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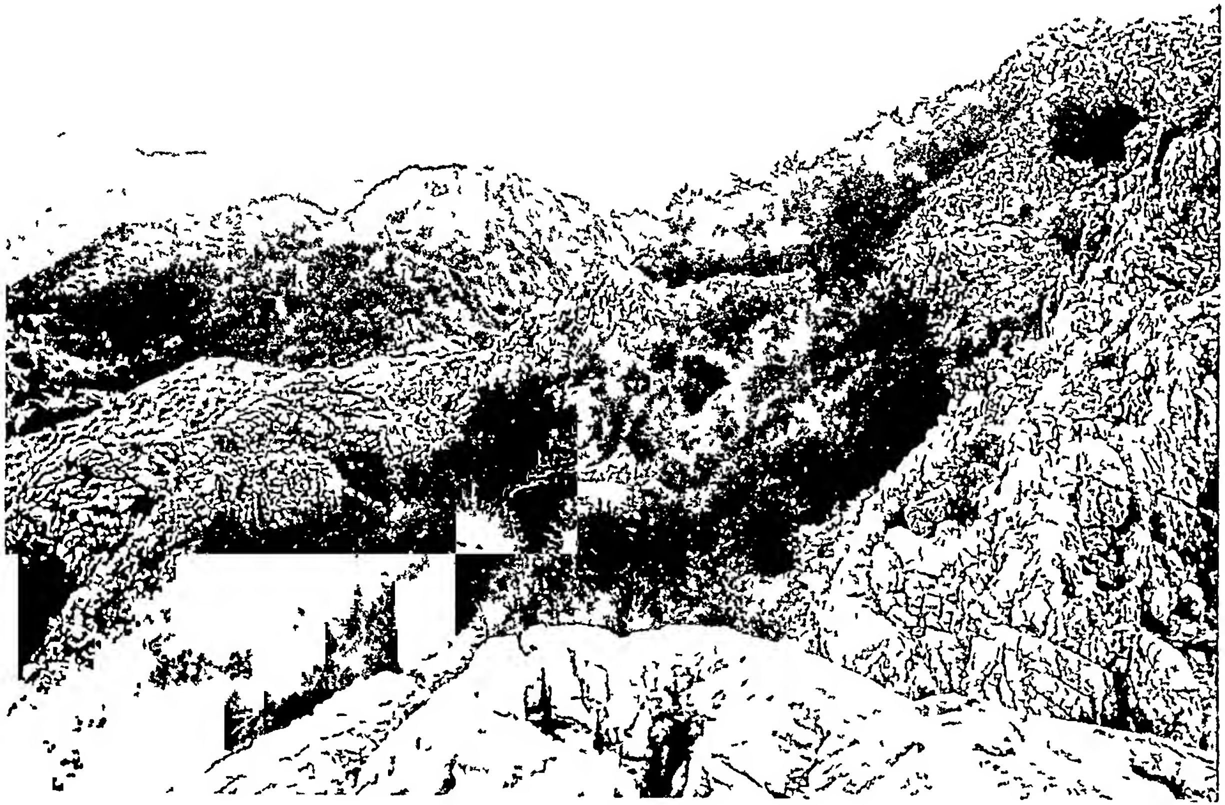

[By courtesy of Henry Hewitt Dean, Esq , J P

PLATE I —A MOUNTAIN SCENE IN MONTENEGRO

THE GROUNDWORK OF MODERN GEOGRAPHY

AN INTRODUCTION TO THE SCIENCE OF GEOGRAPHY

BY

ALBERT WILMORE, D Sc (LOND)

F G S , F R.G S

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TO HIS FRIEND

A L T

THE AUTHOR INSCRIBES THIS BOOK
IN GRATEFUL ACKNOWLEDGMENT
OF MUCH SYMPATHY AND HELP IN
HIS WORK AS A TEACHER OF
GEOGRAPHY

PREFACE TO FIRST EDITION

THE writer of a book on Geography can scarcely hope to be really original, but every writer or teacher may emphasise those parts of the science which appeal most strongly to him, or which seem to him to be most important In this book the author has exercised this privilege freely, and has followed what appears to him to be a natural sequence It is perfectly obvious, however, that other writers may prefer a different order, and may choose to emphasise other aspects of this wide science

Limits of space have necessitated the sacrifice of Mathematical Geography and Cartography, and the important branch Oceanography is only incidentally mentioned The author has had in view a book which may provide, within moderate compass, an introduction to the so-called "New Geography" It is hoped that not only the student but also the intelligent general reader may find the book of some interest, and that it may serve as a preparation for, and a stimulus to, the reading of one or more of the excellent monographs or "Regional Geographies" now available in English The admirable series "The Regions of the World," edited by Mr Mackinder,[1] and the stimulating "Europe," by Prof Lyde, may be mentioned as examples of books to which the present "groundwork" may possibly serve as an introduction

[1] Rt Hon Sir H J Mackinder

PREFACE TO SECOND EDITION

It was pointed out in the Preface to the First Edition that certain phases of geography had been sacrificed owing to limitations of space Experience has proved, however, that modern studies demand the inclusion of these phases, and advantage has been taken of the call for a new edition to add fuller treatment of them

The Author wishes to thank numerous reviewers, first of all for their kindly notices of the book, and still more for many valuable suggestions which are incorporated in this Edition

He is especially indebted to two of his colleagues, Mr L F Richardson, who has given helpful criticism in connection with the new chapter on "Climate and Weather," and Mr G Cruickshank, who has given valuable advice on the subject of "Mathematical Geography" Mr A N Wilmore has again helped in many ways, especially in drawing many of the maps and diagrams, of which a considerable number are incorporated in the added chapters

Considerable additions have been made to the Bibliographies at the ends of the original chapters, and a fairly extensive list is added to the new matter It will be obvious that the reading of Chapter XIX on "Oceanography" may well follow Chapter VIII, and that Chapter XX on "Climate and Weather" may be read after Chapters XI and XII.

PREFACE TO THIRD (REVISED AND ENLARGED) EDITION

THIS new Edition has been thoroughly revised and considerably enlarged, and some desirable readjustments have been made Additions have been made to several of the chapters, and a new chapter has been added dealing with Processes and Agents of Denudation

Statistics occupy but a subordinate position, and are used only in so far as they give precision to the study in hand Statistics are proverbially changeable, and the last ten or twelve years have been particularly trying, it is assumed, however, that the rapid fluctuations of the post-war years are now giving place to more settled conditions, and the years 1928–30 have been selected in the hope that their statistics may prove fairly representative of the present age

The Bibliographies have been thoroughly revised and generally much extended, most of the books which are known to be out of print have been omitted, but a very few classics will always deserve a place, although some date back for more than half a century, they still figure in the lists

The author is greatly indebted to readers in many parts of the world for suggestions In a book of this ambitious character a writer cannot hope to be quite free from slips, he hopes, however, that no very serious errors have been allowed to pass, and he confidently trusts to the continued indulgence of a public which is far wider than he ever hoped to reach

A W

1931

Messrs Gregory, Bottley & Co, of Church Street, Chelsea, have made a collection of minerals and rocks to illustrate this book They will gladly supply particulars on request

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THE GROUNDWORK OF MODERN GEOGRAPHY

INTRODUCTION

GEOGRAPHY is the science which describes the relief of the earth's surface, and which deals with the phenomena taking place upon that surface. The strict etymology of the word Geography (*ge*, the earth; *grapho*, I write or describe) might appear to limit it to a mere description, but by almost universal consent the *science* now includes not only a description of the surface forms of the earth's crust, but investigates and describes phenomena and endeavours to explain results.

It is a composite and synthetic science, relying for its data on the more distinctive or specialised sciences, such as astronomy, geology, meteorology, and biology. There is no definite limit between astronomy and geography, or between geology and geography. On the other side, history and geography have much ground in common. The science is as composite in character as it is synthetic in its relationships, and consequently contains many interrelated and well-understood subdivisions. Dr. H. R. Mill, in the stimulating Introduction to *The International Geography*, edited by him, gave a graphical representation of the departments of this synthetic science, and their relation to each other. Geography he represents as a pyramid with a broad

base of Mathematical Geography On this rests Physical Geography, and on this again Biological Geography Anthropogeography rests on Biological Geography, and the apex of the pyramid is Political Geography

It is obvious that in such a synthetic and composite science different writers and teachers may attach different degrees of importance to the various branches of the subject In the present volume, Geography is especially regarded as the science which deals with the earth's surface as the home of man The various surface-forms and the rock-contents very largely limit and determine man's varied activities, and to these must be added the factors of climate, which constitute another phase of man's "physical environment" The distribution of the ordinary animal and plant life is more regularly limited and controlled by surface-form and climate, but man has learnt to react upon and control his environment, and to combat his limitations

The book begins, therefore, with STRUCTURAL GEOGRAPHY, including in this an account of surface-forms and rock-contents, and then passes on to the elements of CLIMATIC GEOGRAPHY THE GEOGRAPHY OF PLANTS AND ANIMALS follows naturally, and leads up to HUMAN GEOGRAPHY, which includes a brief consideration of some aspects of political and Economic Geography A final chapter deals with MATHEMATICAL GEOGRAPHY AND CARTOGRAPHY

SECTION A

THE STRUCTURE OF THE EARTH'S SURFACE, OR THE PRINCIPLES OF STRUCTURAL GEOGRAPHY

CHAPTER I

THE MATERIALS OF WHICH THE EARTH'S CRUST IS MADE

THE earth, on the surface of which we live, is almost spheroidal in shape. This globe has an irregular surface, which is partly covered by water and wholly by the atmosphere. The surface, and a very slight distance below, are the only parts which are accessible to man and which he can directly study by experiment and observation. The diameter of the earth is about 8000 miles [1], the thin surface layer which man has been able to study directly is not more than 10 miles in thickness at the most. The borings which have been made in search of coal, or metals, or water, are the merest pin-pricks in the great globe.

This comparatively thin outer *crust* is of very great importance to man, however, not only because he lives on it, but because its nature and contents influence him at every point. It consists of different kinds of rocks,

[1] See p. 442.

and hence is known as the crust of the *lithosphere*[1], the covering of air and the partial covering of water are known as the *atmosphere* and the *hydrosphere*[1] respectively

The rocks of the crust may be seen by removing the superficial covering of vegetation and soil, they may be studied in sea-cliffs and river-cuttings, in many a hillside and mountain scarp, and in excavations made by man for various purposes By comparing the rocks in different exposures it is seen that there is a great variety of them, in one place the rock may be hard granite, in another soft white chalk, in another fissile shale or slate The geographer soon realises that the whole character of a region depends very largely upon the rocks which occur at the surface, and it is obviously desirable that he should know something of the origin and classification of these rocks

The intimate study of the nature and origin of rocks and the method of their classification is a branch of the science of *Geology* Rocks will be studied here more from a geographical than from a geological point of view, borrowing from the latter science just as much as may enable the student to understand how the varied features of the earth's surface depend upon the nature and position of the rocks

Sedimentary Rocks—The most cursory examination of many rocks shows them to be similar in composition and in general character to the deposits which are now being formed in shallow seas, and especially in gulfs and estuaries and lakes Thus the gravel beds of Blackheath are very similar to the gravels or pebble-beds seen on many parts of the sea-coast The sandstones which form so large a part of the Pennines are in general composition quite like the deposits of the

[1] Greek *lithos*, a stone, *atmos*, vapour, *hydor*, water, and *sphaira*, a ball or circle

shallower parts of such an estuary as the Dee, or Morecambe Bay, or Solway Firth. The clays of the "Clay-vale," which extends diagonally across England from Oxford to the Wash, are very similar to the muds formed in the estuaries of some of the larger rivers of Western Europe.

All such rocks consist for the most part of material which has been worn from pre-existing rocks by the ordinary processes of erosion, chiefly by frost, rain, and rivers, and by the sea. They are called *Sedimentary*[1] from the way in which the material has been deposited. They are also known as *Aqueous*, because they have been deposited in water *usually*. The names Aqueous and Sedimentary are not strictly interchangeable, however, as some sedimentary rocks are wind-formed. This is the case with many desert sands, which largely consist of particles detached from rocks by great and sudden changes of temperature. In deserts small rock fragments may be driven by the prevalent, steady winds for great distances, and immense deposits of such sands are found in and near many of our tropical and sub-tropical deserts. The *Loess* of China—a deposit which has a maximum thickness of over 3000 feet—is clearly *sedimentary*, but it is not aqueous as a rule. It is probably for the most part wind-borne, and consists of fine rock-dust blown outwards from the middle of the great Eurasian continent by the winds which blow with great regularity from the regions of winter high pressure.

It is quite obvious, too, that mingled with the mud and sand deposited in shallow seas, there will be many kinds of remains of organisms, especially of those with hard parts which are not dissolved readily, such as corals, crinoids, and mollusca. Under certain circum

[1] Latin: *sedeo sedere*, to sit, to settle. Latin noun, *sedimentum*.

stances, and more especially in the warmer, shallow seas, organic remains predominate over the other constituents, and an *organic rock* is formed, in this case called a *limestone*, because the organic fragments are chiefly composed of Calcium Carbonate or Carbonate of Lime ($CaCO_3$) On this account, limestones may be grouped with the sedimentary or aqueous rocks

There is yet another group of rocks which may be included loosely with the above Deposits of vegetable origin are formed, either on the land where the vegetation has grown, or in shallow lakes and lagoons into which drifted vegetation has been carried in large quantity, and where it has mingled with the aquatic vegetation of the lagoon itself The *peat* of the moorlands has been formed by the long-continued death and decay of moorland vegetation, such as sphagnum or "bog-moss," sedges, rushes, ferns, and other plants Fen-peat has been formed similarly in marshy lowlands by the accumulation of decayed vegetation such as that which grows so luxuriantly in the fen-lands of England, the Netherlands, and North-Western Germany In a somewhat similar way coal-beds of different kinds were formed in past ages of the earth's history from different kinds of plants which then grew in great luxuriance It is quite clear that such rocks are not strictly of the same class as sandstones and shales, they may not be, in all cases, even aqueous, but it is convenient to group them with the sedimentary and aqueous rocks for purposes of study and description

This great class of rocks, therefore, may be classified by the geographer as follows

Sedimentary and Aqueous Rocks

(*a*) Sands, sandstones, coarse sandstones or grits, consolidated pebble-beds or conglomerates The

rocks of this group may be termed the sandy or *arenaceous* sub-class

(*b*) Muds, clays, shales, slates This is the clay-shale or *argillaceous* sub-class

(*c*) Limestones, made up chiefly of the hard calcareous parts of sea-organisms, animal, or plant (the former predominating) This is the *calcareous* sub-class

(*d*) Rocks of vegetable origin, peat, brown-coal or lignite, coal, cannel-coal, anthracite This is the *carbonaceous* sub-class

Igneous Rocks —This great class of rocks is quite different in origin from those considered above The common feature of these rocks is that they have all solidified from the molten condition, but just as in the case of the sedimentary class, there are great differences in the characters of the numerous rocks included in the igneous class

The simplest and most obvious sub-class includes those rocks which have been poured out in the molten condition from cracks and fissures in the earth's crust, or from the craters or flanks of volcanoes These are the *lavas*, which, when cooled and solidified, are named *volcanic* rocks Lavas vary very considerably not only in their chemical and mineralogical composition, but also in their physical properties, some are more liquid than others—they possess a lower melting-point, and hence when poured out on the earth's surface from a crater or fissure they flow much more perfectly and extend to a greater distance Some lava-flows are thus of great extent while others are much more limited in area Modern lavas from the volcanoes of Iceland have covered scores of square miles, while, on the other hand, in many parts of the world there have been poured out viscid lavas which

have flowed very imperfectly and which have solidified somewhat after the manner of the tallow on an old-fashioned tallow candle The outpourings of highly liquid lava are of importance to the geographer because extensive plateau areas in the Deccan of India, in South Africa, in Eastern Africa, and in the region west of the Rocky Mountains in North America are largely occupied by these solidified fissure-lavas or plateau-lavas, as they are often called

Another type of volcanic product consists of the fragmentary material ejected in explosive outbursts, this may vary from the finest impalpable dust to large bombs or irregular fragments, and the solidified deposits thus formed may vary in texture from a fine-grained "ash" to a *breccia* made up of large, irregular fragments The explosive outbursts of some volcanoes, such as, for example, Vesuvius, scatter enormous quantities of such fragmentary material over the region in the immediate neighbourhood of the volcano It was chiefly such showers of volcanic ash that buried the cities of Herculaneum, Pompeii, and Stabiæ in the classic eruptions of A D 79

It may be pointed out that some deposits formed in this manner have certain features in common with many of the sedimentary rocks already described Submarine deposits of fragmentary volcanic matter are known which contain fossils, and stratification is often a marked feature of these "tuffs" or beds of volcanic ash At the summit of Snowdon may be seen beds of well-stratified volcanic ash in which fossils are quite common

In many volcanic regions these fragmentary volcanic rocks cover vast areas, and provide by their weathering a very fertile soil They are thus of considerable interest to the geographer as well as to the geologist In a subsequent chapter dealing with "land-forms,"

it will be shown how the familiar mountains known as volcanoes are in large measure built up of volcanic ash, breccias, and lava-flows

Another group of igneous rocks includes those which have not a superficial origin, but which have solidified below the surface and have come within the scope of the geographer owing to the removal of the overlying rocks by denudation Those which are of greatest importance are as follows

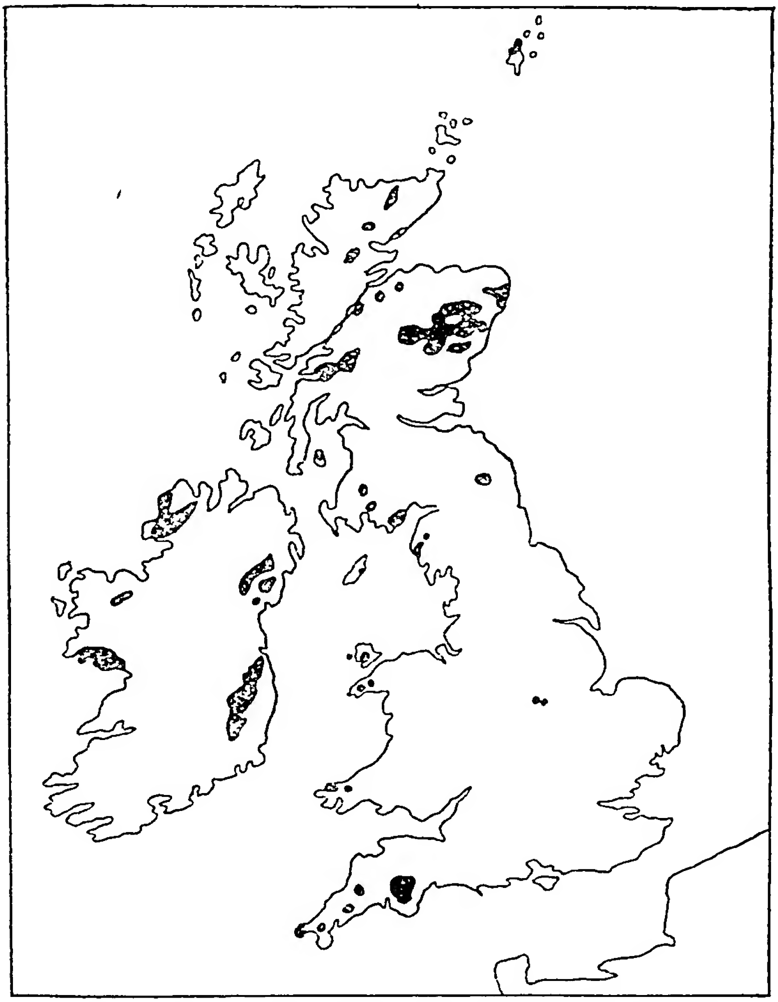
(*a*) Sheet-like intrusions of molten matter, the latter having come from some subterranean source, and the intrusions having been thrust into rocks already existing, more or less along their bedding-planes or planes of stratification[1] Such sheets are known as "sills", they are not easily distinguishable from lava-flows in many cases, and their geographical relationships are often very similar

(a_1) Intrusions having a more or less vertical direction or trend, which may be in the nature of vertical or highly inclined sheets, "pipes" of varying size and extent, which probably communicated with some deep-seated reservoir of molten rock, and which probably served as feeders for long-continued outpourings of lava To these may be added the solidified matter in necks and cauldrons of volcanoes from the craters of which lava was poured out and fragmentary material ejected

(*b*) Large masses or bosses of varying size and shape which have solidified at somewhat greater depths within the crust, which have in consequence of their depth solidified slowly and under great pressure, and the individual constituent minerals of whose rocks have been more perfectly developed in consequence

[1] Latin *stratum*, a layer or bed

Those under (*b*) are the sub-class known as *Plutonic Rocks*, those under (*a*) and (a_1) are generally termed *Intrusive Rocks* It is not easy, in many cases, to decide whether a rock should be described as plutonic or intrusive [1]



The regions where granite crops out at the surface are shown

FIG I —CHIEF GRANITE AREAS IN BRITISH ISLES

[1] See the table on p 475

Among the Plutonic rocks granites are the most important to the geographer, and basalts among the Volcanic rocks sub-class, because these are found in larger quantities than the other types Granite forms the surface rock in several of the wilder mountain districts in the British Isles This rock now appears at the surface because the rocks under which it consolidated at considerable depths have been removed by denudation Basalt and rocks closely related to it in composition form the greater part of the volcanic plateau of Antrim, including the interesting rocks of Giant's Causeway Fingal's Cave, in the island of Staffa, is a remnant of a similar wide sheet of basaltic rocks of the same age as those of Antrim

Metamorphic Rocks—The rocks of which the earth's crust is composed are always being acted upon by many natural forces and agents which produce in them some kind of change, either chemical or physical Water penetrates those which are readily permeable, and flows along the bedding-planes and cracks of those which are less permeable, and by means of its own solvent action and the substances it contains in solution it effects, in the course of time, great changes in the rocks through which it passes At great depths, where the temperature is higher than at the surface, water exerts a greater influence and causes changes of a more extensive character Other hot liquids and gases are no doubt present at these greater depths, and changes in chemical composition and physical character must be caused by their action We must take into account the influence of great pressure, both that which is due to the mere weight of overlying rocks and which is called *static* pressure, and that which is due to great lateral movements in the earth's crust and which is called *dynamic* pressure It is not suggested that these various

forces and agents act separately or independently, or even that they can be separated from each other logically Sometimes one or other is of greater importance, but usually their actions are interdependent

Great changes are thus produced in all rocks, the amount of change depending on the time during which the rocks have been acted upon, and on the intensity and character of the agents and forces concerned There are some rocks which have been changed so completely that their original characters are practically destroyed, and it is by no means easy in many cases to determine the original nature of the rock Such completely changed rocks were called *metamorphic*[1] by the great geological teacher Lyell, and in his day (his teaching extended from about 1830 to 1875, and he first used the term metamorphic in his "Principles of Geology" in 1859) very little was really known of the origin of the rocks of this great class Thanks to modern studies, however, we now know that they were originally igneous or aqueous rocks, which have been so changed in character as to deserve a new name It is to this great class of re-formed or re-moulded rocks that the name metamorphic is applied now

Such rocks are of widespread occurrence, and as they give rise to distinctive types of scenery, and are often found to contain considerable quantities of metallic ores and other "minerals," they are of great importance to the geographer The chief kinds are those named *Gneiss*[2] and the *Crystalline Schists*[3] Most gneisses are almost certainly altered plutonic rocks, many crystalline schists are just as certainly altered aqueous rocks A

[1] Greek *meta*, change, *morphe*, form or character

[2] *Gneiss*, a German word of unknown origin

[3] Greek *schistos*, divided

typical gneiss consists of irregular folia of a number of minerals, such as quartz, felspar, and mica, such a gneiss is probably a plutonic rock of the granite sub-class completely altered A schist usually consists of finer folia of quartz and a mineral such as mica Metamorphic rocks cover very large areas of the earth's surface

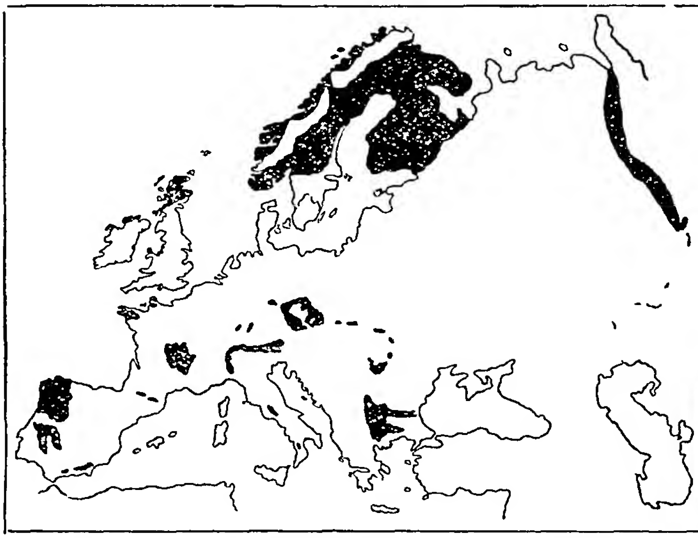


FIG 2 —MAP OF METAMORPHIC AREAS IN EUROPE

The map (Fig 2) shows the European regions where such rocks are predominant

There are thus three great classes of rocks

Aqueous and Sedimentary Rocks
Igneous Rocks
Metamorphic Rocks

The surface of the earth consists of these in very different proportions in different regions Sometimes one class occupies a very wide area, as, for example, the metamorphic rocks of Finland and Northern Scandinavia

On the other hand, the British Isles contain representatives of all the classes and almost all the sub-classes, though, as we shall see later, certain well-defined geographical districts in the British Isles are occupied almost solely by one kind of rock

The geographer must constantly ask what are the rocks which occur in a region, because the scenery, the fertility of the soil, and the occupations of the people are so largely dependent upon the rocks As already indicated, granites, for example, are hard, and usually give rise to infertile moorland or mountain conditions Recent volcanic rocks, especially of the more basic types, weather into very good soil and give rise to some of the most fertile regions on the face of the earth Much of the wonderfully fertile soil of Japan is derived from volcanic ash, as also is the highly productive soil in the neighbourhood of Naples Metamorphic rocks are generally hard, and are associated with rugged scenery and infertile soil Aqueous rocks are usually associated with gentler and softer scenery and with more fertile soil, though there is a considerable difference between the conditions produced by the various types In the chapters dealing with land forms, and in the section dealing with economic geography, further reference will be made to some of the characters and properties of the different classes of rocks

The Relative Age of Rocks

There is another point of view from which rocks must be considered by the geographer, and that is their *relative* age The *actual* age of even the youngest rocks is practically unknown, certain exceptions being, of course, some volcanic rocks and aqueous rocks formed within historic times We can make more or

less plausible estimates of the age of some of the stratified, aqueous rocks, and of the time required for their formation, but at the best they are only estimates, and may possibly be very wide of the mark. We can, however, distinguish older from younger rocks, and so make a relative chronology of their formation.

In the case of some of the igneous rocks, more especially the plutonic sub-class, age is not of very much importance to the geographer, as plutonic rocks of very different ages, but of the same general composition, produce, on the whole, the same general types of scenery. Thus the granites of the central Highlands of Scotland, of Dartmoor, of the Wicklow Hills and of the Mourne Mountains give rise to very similar geographical conditions, though they are certainly of different ages.

It is, however, somewhat different with the aqueous rocks. Here age is of very great importance, and the student of geography must be acquainted with the elementary principles and the terms used. The stratigraphical geologist determines their relative ages by using two well-understood principles. The first is that of superposition: it is obvious that, in the case of normal aqueous rocks occupying their original positions, newer rocks must overlie older ones; that follows from the method of formation. This point may be briefly illustrated. The Chalk of the English North Downs and the Chiltern Hills rests on a variable deposit of sand, and this in turn on a clay. The clay, called the Gault, is obviously the oldest or earliest formed of these three formations, and the Chalk is the newest. The sequence is as follows:

Chalk
Sand (" Greensand ")
Clay (" Gault ")

In the Pennine moorlands and on their flanks are the

beds containing our coal-seams, the series is called the Coal Measures These rest on a thick series of coarse sandstones or grits, and these in their turn overlie a thick series of beds which are mostly calcareous The coal measures are the newest of these three formations, the limestones (the calcareous series) are the oldest Tabulating as before, the sequence is

Coal Measures

Grits (" Millstone Grit ")

Limestone Series (" Carboniferous Limestone ")

The second principle used is not so obvious, but its enunciation came as the result of patient research combined with brilliant insight, just as with so many other important scientific generalisations William Smith, an English engineer, a little more than a century ago, not only clearly stated and emphasised the principle of superposition briefly outlined above, but he was the first to lay down the principle that rocks of the same age contain, broadly speaking, the same kinds of fossils, and succeed each other in the same general order It is thus possible to compare rocks in different regions For example, there are rocks in North America which contain the same general fossils as those found in the limestones of the Pennines, and we have no hesitation in saying that the two sets of rocks are of the same age approximately The well-known shell-beds of East Anglia contain the same fossils, in general, as certain beds in the plains of Western France, we unhesitatingly say that these East Anglian and French formations are of about the same age The fossils in these latter beds are absolutely different from those found in the Pennine rocks Hence these deposits are not of the same age as the East Anglian beds

Relying on these principles, the geologist has been able to arrange a table of aqueous rocks according to

their relative ages, using descriptive names derived in some cases from a region where the particular rocks either were first studied, or are very well developed, or from some fairly obvious feature of the rocks themselves The student of geography continually uses the geologist's relative time-scale of rocks Such an abbreviated scale is given here, a fuller one will be found in the Appendix, pp 476–78

Recent and Pleistocene		
CAINOZOIC or TERTIARY		Pliocene Miocene Oligocene Eocene
MESOZOIC or SECONDARY		Cretaceous Jurassic Triassic
PALÆOZOIC	(UPPER)	Permian Carboniferous Devonian
	(LOWER)	Silurian Ordovician Cambrian
Pre-Cambrian and Archæan		

THE LITHOSPHERE IN RELATION TO THE WHOLE EARTH

The student of geography is mainly concerned with processes and events which may be observed on the earth's surface, but he cannot be indifferent to what takes place in deeper parts of the lithosphere, and he soon finds himself inquiring as to the relations between the lithosphere and the other parts of the sphere The chemical constitution and the physical properties of the rocks forming the lithosphere are open to his in-

vestigation, and there is now a vast amount of accumulated knowledge at his disposal. The density of the rocks of which the lithosphere consists varies from little more than 1, in the case of certain lignites, to about 3.3 in some heavier basalts. Taking an average, and allowing for quantitative occurrence, it seems quite certain that the average density of the observable crust is between 2.5 and 3, probably between 2.6 and 2.8, and very possibly about 2.67. The density of the whole earth is not far from 5.5, or the average density of the rocks of the observable crust is slightly less than half that of the whole earth. It is assumed from this that the earth's interior is much heavier than the lithosphere, and the belief has grown up that the earth has some approach to a zonal structure.

It is suggested that the greater part of the earth's interior consists of nickel-iron; this is the barysphere. Between the lithosphere and the barysphere is a zone of different constitution, about which there are different theories or suggestions. Some speak of it as a weak, plastic layer; others suggest a zone of liquid basalt. Some suggest well-marked discontinuity; others suggest that it is a zone which passes up *gradually* into the lower parts of the lithosphere, down into the outer parts of the barysphere. This viscous, plastic, or liquid zone is (so it is suggested) at a depth variously estimated at from 30 to 60 miles; above this the lithosphere behaves generally in a way which can be understood from our observations made at and near the surface.

The lithosphere is made up of rocks of different densities, but these rocks are not distributed altogether promiscuously; it is found both by observation and experiment that the lighter rocks occur in larger quantity in regions of high mountains and plateaux, and the heavier rocks under the seas and the great contin-

ental plains The rate of vibration of a pendulum of given length depends upon the intensity of gravity, and the direction of a plumb-line is influenced by the attraction of great elevated land masses Observations of both of these teach that the materials of the lithosphere are lighter on continental plateaux, heavier on the sea floor

The anomalies stated above are explained by the Doctrine of Isostasy, which suggests that the mass of matter standing upon a given area is approximately the same whether it be under a highland region or a lowland Thus, stated quite crudely, a column of lithosphere material measured from the level of no strain at, say, 40 miles below the mean surface of the earth, may be 45 miles under the Himalayas, 37 miles under the neighbouring Indian Ocean—and these will be of the same mass per unit area Merely as an illustration such would be the case if one were of the density of light granite, the other of a heavy basalt

If there be, in fact, such an isostatic balance in the lithosphere, it follows at once that there must be a corresponding isostatic compensation The material of high mountain masses and plateaux is for ever being removed by erosion and carried to the lowlands and seas, it is suggested by some geologists that there is an underflow of plastic or liquid material in the opposite direction, and so the isostatic balance is maintained

If we accept the doctrine or suggestion of isostasy and the existence at a very moderate depth of a plastic earth-layer, it becomes no longer difficult to visualise movements in the "solid" earth's surface movements not merely involving changes of level, but movements in a lateral direction which cause changes of latitude or longitude, or both, of a place It is claimed that such changes must now be accepted as among the undisputed

facts of nature It would not be a difficult farther step to believe that whole segments of the crust might actually slip on the crushed, plastic layer Such, in its extreme form, is the so-called Wegener Theory, which postulates the "drift" of the continents, or, to quote a concrete example, the formation of the Atlantic by the drifting or slipping westward of the Americas from the Eur-African land-mass

The Doctrine of Isostasy is still doubted by many geologists, and the Wegener Hypothesis is probably still farther from full acceptance There is already a considerable literature on the subject scattered through the Geological and Geographical journals *The Encyclopædia Britannica*, 12th edition, 2 vols , and the so-called 13th edition, 3 vols , contain good articles on the subjects

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CHAPTER II

VOLCANOES AND VOLCANIC MOUNTAINS

THE surface-form of the earth is profoundly affected by the ejection of material from within the crust Not only is its contour modified, but the presence of ejected material and the frequency and manner of its ejection are of great importance to man in connection with the habitability of various regions Hence we must make at least an elementary study of the *results* of volcanic phenomena The physics of eruptions, the study of underlying causes, and the precise sequence of events belong to the domain of Physical Geology, and they will only receive incidental reference here We are concerned with the geographical aspect of the subject

For our purpose a volcano may be defined as a vent from which gaseous and also either solid or liquid materials, or both, are ejected The important substances to the geographer are the liquid rock-material called *lava*, and the solid material known by various names

Lava, or molten rock-material, varies very considerably in chemical composition and in physical properties All lavas consist chiefly of mixtures of the silicates of alumina, soda, potash, lime, magnesia, and iron oxide In classification, those lavas which contain large proportions of the oxides of lime, magnesia, and iron are called basic lavas These have lower

melting-points, and thus remain liquid much longer than the acid lavas which have higher melting-points It is clear, therefore, that the chemical composition and associated physical properties of lavas will have a great influence on the form of accumulation produced by their extrusion from the earth's crust

Much of the material which was undoubtedly molten within the crust is not ejected in that condition It has already become solid within the "volcano," and is ejected in explosive outbursts as showers of solid matter of varying form and size The larger pieces are known as *volcanic bombs*, smaller and more or less rounded pieces are known by the Italian name, *lapilli* Very fine *volcanic dust* is often ejected in large quantities, the name needs no explanation *Volcanic ash* is a vague term used to describe indefinite mixtures of dust, lapilli, and irregular fragments When this has set and hardened it is usually spoken of as *tuff*, if a number of the fragments of which it is composed are somewhat angular and irregular in form and size, the resultant consolidated deposit is a *volcanic breccia*

The fragments in an ash or breccia will obviously show some or other of the characters of the lavas from which they have been derived Some fragments are *glassy*, some are *ropy* If they are "cindery" in appearance the term *scoria* is generally applied The name *pumice* is used for highly vesicular material, which is clearly the solidified froth or scum at the surface of a lava-flow, the vesicular character being caused by the escape of steam There are, as may be expected, all sorts of combinations of these various states Many schools, colleges, and museums have good collections of examples If at all possible the reader should inspect such a collection

Extrusion of Lava—It is now generally accepted that lava may be extruded from two kinds of vents

Almost all the lavas which have been poured out within the historic period have come from some localised opening in the crust, round which, as we shall see later, a volcanic mountain is built up. It is believed now, however, that in addition to these localised lava-centres, molten rock-material has often been poured out from long lines or fissures in the earth's crust.

Fissure-lavas.—It seems highly probable that immense fissure-lavas have been extruded in more than one comparatively recent geological period, if we may judge from the nature and extent of the resulting lava-plateaux. During the Tertiary era lavas of this type were extruded over vast areas in Washington, Oregon, and Idaho, in the great plateau-regions west of the Rocky Mountains. In the same era immense fissure-lavas were poured out in the north-west of the Deccan of India, where there are found some of the most extensive lava-flows known. To the same great era belong the plateau-lavas of the far north-west of the British Isles, including Antrim, Mull, and the more distant Faroes. All these great lava-flows are of basic composition. With the possible exception of certain Icelandic eruptions which took place in the eighteenth century, such fissure-lavas or plateau-lavas do not seem to have been formed within the historic period.

Volcanic Mountains, "Volcanoes."—A volcano, as usually understood, begins with a localised crack or opening in the crust, from which material is ejected. As already pointed out, this ejected matter may be gaseous, liquid, or solid. By the accumulation of the solidified rock-material a *mountain* is in time built up, which, in the nature of things, will be more or less conical in shape. The conical mountain—popularly known as a *volcano*—may be composed wholly of solidified lava or wholly of fragmentary matter thrown out by ex-

plosive outbursts, but in the vast majority of cases the conical pile consists of varying mixtures of the two kinds of ejected matter

Lava-cones —In several volcanic regions there are found conical mountains, built up, entirely or almost entirely, of lava The shape of the cone depends upon the composition of the extruded molten matter Acid lavas are highly viscous, with a liquidity somewhat like that of thick treacle or tar, and they tend to form dome-like masses Such domes, of recent formation,

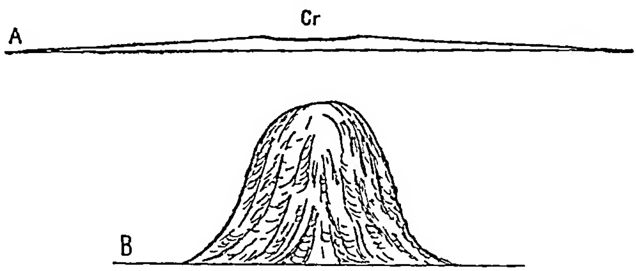

FIG 3 —HAWAIIAN CONE AND "MAMELON"

A Diagram of a Hawaiian Cone of very basic lava Crater at Cr
B Diagram of a "Mamelon" composed of viscid acid lava

which occur in the island of Réunion, in the Indian Ocean, are known there as "mamelons" They consist of lava of rhyolitic composition Cainozoic and Pleistocene lava-cones, which are dome-like in shape, are found in the Auvergne and in Bohemia

In contrast with the acid lavas, which tend to form domes, the basic lavas flow much more freely, and extend to a greater distance from the vent The immense lava-cones of the Sandwich Islands, in the Pacific Ocean, are formed of such basic lavas Mauna Loa consists of little else, and it has an enormous bulk It rises to 13,000 feet above sea-level, and the inclination of the sides of the cone varies from 4° to 7° The extrusion

of the lava may be judged from the fact that the volcano is over 50 miles in diameter, and that its crater is over 10 miles in width. If the dimensions of this immense lava-cone are reckoned from the sea-floor, it is at least 30,000 feet high, and its diameter is about 160 miles. Kilauea, a similar volcano in the same island-group, has a crater even wider than that of Mauna Loa.

Cinder Cones and Debris Cones.—Some volcanoes are made up solely of ejected fragmentary matter. Monte Nuovo, a few miles north of Naples, is a classic example. This volcanic hill was formed in three or four days in 1538. It is almost perfectly conical in shape, is 440 feet high, and over 2400 feet in diameter. The structure of the mass may be studied inside the crater, which extends to a depth of about 400 feet from the summit. The cone is built up of fragmentary material, chiefly trachytic scoria and cinder, in which there are occasionally found bits of the sedimentary rock which formed the ground on which the debris cone was built, and through which the eruptive forces had to make a passage. Bits of Roman pottery were found by Lyell during his examination of the mountain in 1859. That famous teacher collected in his *Principles of Geology* excellent contemporary accounts of the formation of this "new mountain," and he also gave a clear description of its structure and relation to neighbouring volcanoes. Similar cinder cones of over 1000 feet high have been known to be built up in a very few hours.

Volcanic mountains, almost or quite exclusively made of debris, are well known in the Auvergne, in Java, and in Mexico. In Java there are mountains reaching over 9000 feet in height, with a diameter of 10 miles, which probably consist of fragmentary material. There is a series of small cones on the Mexican plateau,

of which Jorullo is perhaps the best known These consist of cinders, scoriæ, and similar rock-fragments, and were formed for the most part in a single series of eruptions in 1759 Izalco, in San Salvador, Central America, is another famous example of a cone, mostly built of volcanic debris This new volcano was apparently first formed in 1769 It is still active, and has now reached a height of about 2600 feet

Composite Volcanic Mountains—Most volcanoes consist of successive lava flows and alternating showers

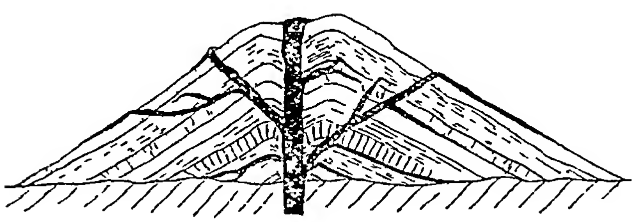

FIG 4 —DIAGRAMMATIC SECTION ACROSS AN IDEAL COMPOSITE VOLCANO

The different kinds of shadings represent successive additions to the volcano The composite volcano is represented as resting on a floor of rocks, through which the lava is forced up from some reservoir below

of volcanic debris, and represent the efforts of a long series of eruptions The structure of such a composite cone may be illustrated diagrammatically by such an ideal section as that given in Fig 4 Vesuvius has obviously such a structure, for its history is known for nearly two thousand years, and the successive lava-flows and deposits of ash, lapilli, etc, have been very carefully studied during the last one hundred and fifty years Enough is known of the history and structure of Etna, Teneriffe, Cotopaxi, Popocatapetl, Fujiyama, and many other volcanoes to assure us that their

general structure is the same as that of Vesuvius It has very frequently happened that the internal structure of a volcano might have remained doubtful were it not that erosion by frost, rain, and small streams has proceeded sufficiently far to reveal the successive lavas and showers of debris of which the mountain has been built up

The building of a large volcano has often commenced with the ejection of cinders and other fragments, and a debris cone has been formed This has been followed by the ejection of lava, which has either welled up and flowed over the rim of the crater, or has forced a way through cracks in the sloping sides of the mountain As the volcano has grown bigger the explosive forces have been unable to eject material from the summit of the crater (which has been closed by solidified lava and debris), but have been powerful enough to blow away one side, or a portion of one side, of the mountain Thus the internal structure of a volcano is often completely revealed The original greater Vesuvius, known as Somma, was thus breached by the historic outbursts of A D 79 The modern active cone is contained within the broken crater of that greater volcano, Somma Several such breached volcanoes, of a much smaller size, are to be seen in the volcanic Auvergne, and similar structures are common elsewhere

The structure of a composite cone is frequently further complicated by the extrusion of lava and the ejection of debris at various points on its flanks Thus a small volcano is built, reproducing most of the features of the parent cone Such *parasitic cones* are a well-known feature of Europe's greatest modern volcano—Etna, in Sicily

Not only do composite cones constitute the majority of volcanoes, but nearly all the larger volcanoes are presumably of this type The following may be men-

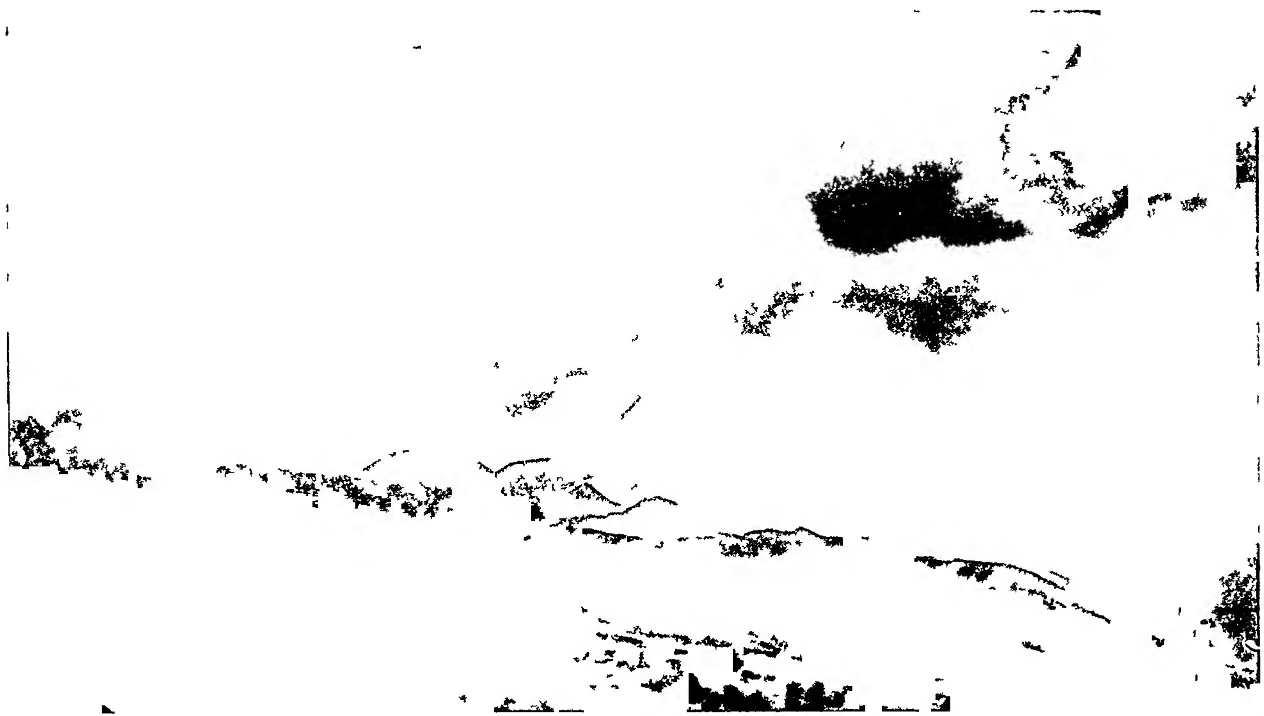

PLATE II.—PARASITIC CONES IN ERUPTION, MOUNT ETNA

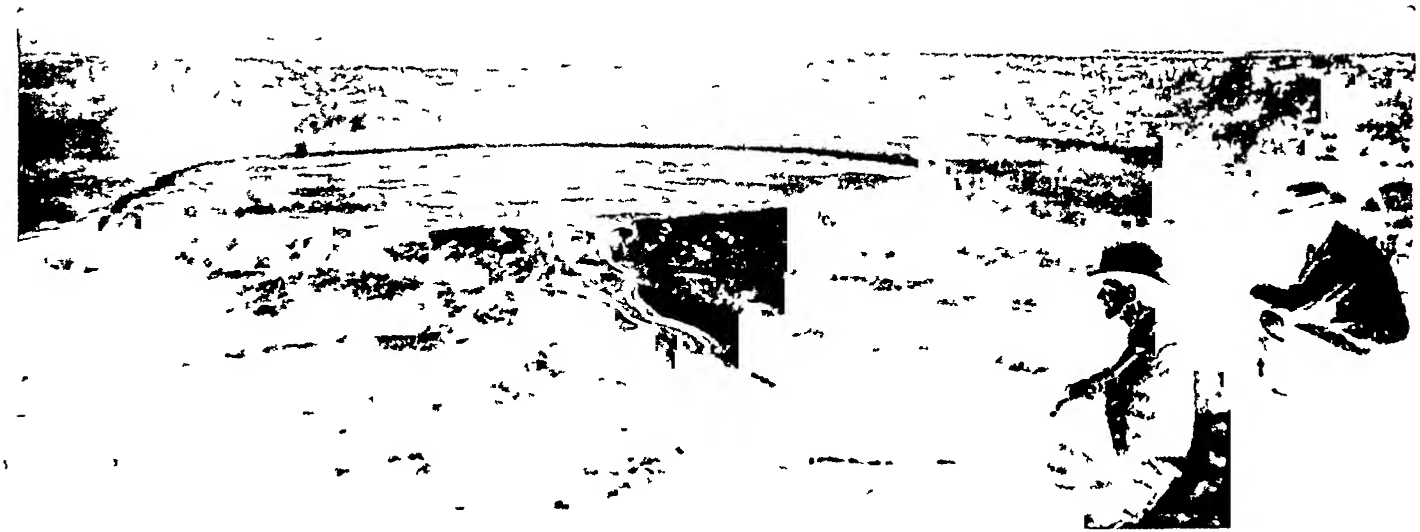

PLATE III.—KILAUEA, THE SECOND CRATER OF MAUNA LOA, SANDWICH ISLANDS, THE WORLD'S LARGEST VOLCANO

The picture shows the famous Lake of Fire

tioned as examples Etna, in Sicily, 10,700 feet Teneriffe, in the Canary Islands, 12,000 feet, the beautiful cone of Fujiyama, in Japan, 12,400 feet, the perfectly formed extinct cone of Shasta, U S A, over 14,000 feet, and Cotopaxi, in South America, 19,600 feet The last named is possibly the highest active volcano in the world The above are, of course, only selected examples

It has been mentioned that subsequent erosion may considerably modify the original conical shape of the volcano This destructive erosion may continue to such an extent that a mountain which is obviously built of igneous matter may show very little indeed of its original shape Denudation may even proceed so far that little except the central plug of solidified lava —that which filled the neck—is left The famous trachytic plug of Mont St Michel in the Auvergne, and the basic neck, Castle Head, Keswick, are well-known examples of such volcanic necks or plugs The subject of the denudation of volcanoes will receive further mention in Chapter V

Distribution of Volcanoes—Mercalli, an Italian geologist, has estimated that there are 415 volcanoes on the earth's surface, of which 231 have been active since the year 1800 Of these latter the distribution is as follows

America, 76
Eastern Asia, 39
Malay Archipelago, 49
"South Seas," 27
Atlantic Islands, 20
Africa, 7, including 2 in Réunion
Europe, 8
Continental Asia,[1] 3

[1] Excluding the eastern peninsulas and islands.

Many of the active volcanoes are situated on or near the edges of continents, very frequently on peninsulas or islands The Pacific Ocean is almost girdled by volcanoes, "The Ring of Fire of the Pacific," so often mentioned in books on geography It is important to notice that round the Pacific are so many of the long lines of younger fold-mountains mentioned in Chapter IV, and there can be little doubt that there is some connection between these and the volcanoes The Atlantic Ocean has no similar series of Alpine mountains with steep, continental edges, and there is no Atlantic girdle of volcanoes The subject is discussed at length in some of the more advanced treatises on Physical Geography, and in works on Volcanoes

Of the 415 active and extinct or dormant volcanoes mentioned above no less than 337, or 88 per cent, are either on the coasts of the Pacific or on islands in that great ocean It is obvious that, in the present geological epoch, the Pacific Hemisphere is the chief seat of volcanic activity To trace out the coastal series of the Pacific we may begin in North Island, New Zealand From there we may follow an almost unbroken series of volcanoes, through the New Hebrides, the Philippines, Formosa, the Loo Choo Islands, the Kurile Islands, and Kamchatka The series is interrupted at the Aleutian Islands to be recommenced on the eastern side of the Pacific, where it may be traced on the western side of the two Americas as a less continuous line From latitude 62° N in Alaska, to latitude 22° N in Mexico, recent volcanic rocks are widely spread, and volcanoes recently extinct are numerous, but there is little present-day volcanic activity In Mexico begins that New World region of volcanic activity, which may be traced with some

interruptions to the southern limits of the American continent Six sub-regions are usually distinguished

(1) The Mexican sub-region —lat 22° N to lat 18° N
(2) The Central American sub-region —lat 15° N to lat 9° N
(3) The equatorial sub-region of Colombia and Ecuador —lat 5° N to lat 3° S
(4) The Peru-Bolivia sub-region —lat 15° S to lat 23° S
(5) The Chile-Argentina sub-region —lat 23° S to lat 42° S
(6) The Patagonia-Tierra-del-Fuego sub-region —lat 42° S to lat 56° S

This Pacific girdle of volcanoes seems to be continued into the Antarctic continent where Mount Erebus and Mount Terror occur

As already mentioned there is no similar girdle of volcanoes round the Atlantic coasts, and the coasts themselves are quite different in type, there being no long series of younger fold-mountains facing the Atlantic Ocean In the West Atlantic are the volcanoes of the West Indies, which, beginning near those of Mexico, extend through the West Indian Islands Mercalli gives nine volcanoes in the Antilles, of which six are active Soufriere and Pelée are well-known, because of their recent activities

Extending lengthways along the Atlantic, from Jan Mayen in the north, through Iceland, the Azores, the Canaries, and Cape Verde Islands, is an interrupted volcanic belt, containing thirty-nine volcanoes, of which twenty are said to be active The majority of these volcanoes are in Iceland

In Southern Europe there are the famous volcanoes of Italy, Sicily, and the adjacent islands, and those

of the Grecian Islands These are the best-known volcanoes in the world, Vesuvius, Stromboli, and Etna having been especially well studied

Volcanoes, both active and extinct, are found in the Caucasus-Armenian region, where the mighty Mount Demavend in the Elburz range is over 19,000 feet high This mountain seems to have reached almost the last stages of volcanic activity

A fine series of volcanoes extends from the Bay of Bengal through Sumatra, Java, and the lesser Sunda Islands to join the great Western Pacific belt, and includes eighty-nine volcanoes, of which forty-nine are considered to be active The most violent explosive outburst of modern times was that of Krakatoa in August 1883, when the greater part of a volcanic island was literally blown away Krakatoa is in the Sunda Strait, between Sumatra and Java

Volcanoes and Fold-Mountains—From what has been said already it is clear that there is some intimate connection between the existence of active volcanoes and the occurrence of long lines of modern Alpine mountains When we take into account volcanoes which have been active in later Tertiary times, in addition to those active in recent times, the connection becomes more striking It may be noted at this stage that most of the Italian and Sicilian volcanoes occur on the inner side of the curve formed by the very modern Apennine Mountains The Apennines are closely associated with the Atlas and Sierra Nevada chains, the whole forming a great Alpine curve, enclosing a deep sunken block of the earth's crust There were volcanoes in the neighbourhood of these mountain chains in the Tertiary era It has been shown that there is a remarkable resemblance in chemical composition between the volcanic rocks of different

parts of this Western Mediterranean region, possibly indicating something approaching a common origin The rocks belong to the same " petrographical province "

Similarly, inside the long curve of the Carpathians are the numerous extinct volcanoes of Hungary and Transylvania, of which those of Schemnitz, the Matra, Tokay, and the Munkacs district are the best known The extinct volcanoes of Teschen, in upper Silesia, and Bohemia are *outside* the Carpathian curve Professor Judd showed, many years ago, that there is a sharp contrast in composition between the igneous rocks on opposite sides of the Carpathian chain of fold-mountains The rocks belong to different petrographical provinces This is another way of emphasising the close connection between the production of tangential folds in the crust and the development of igneous activity These phenomena, so important in geography, are evidently due to some common cause In addition to the above examples, the same intimate connection may be illustrated from many parts of the world

Volcanoes and Rift-Valleys—One of the more remarkable cases, of a somewhat different kind from those discussed above, is that of the famous rift-valley of East Africa This well-known line of fracture extends from the north of Syria, through the Dead Sea, the Gulf of Akaba, the Red Sea, across Abyssinia, past Lake Rudolf, to the Zambesi region Volcanoes, recently extinct or dormant, are associated with this great fracture at various points, more especially in the Red Sea region, where five active and seven extinct or dormant volcanoes have been enumerated Farther south are Teleki, which was in full eruption in 1894, Kenya, an extinct volcano over 18,000 feet high, whose cone is built of lavas and tuffs, and Kilimanjaro, nearly 20,000 feet high, with its peaks clothed in

snow A much smaller volcano, not far from the great and probably extinct Kilimanjaro, was in eruption in 1880

Volcanic action accompanied the formation of other rift-valleys, for example, those of the Rhine and the Midland Valley of Scotland These rift-valleys are of very different ages, but in each case volcanoes were formed as a consequence of, or at least in connection with, the sinking of portions of the crust Other illustrations are unnecessary, enough has been said to show that volcanoes are intimately associated both with folding and faulting of portions of the earth's crust, and that both the types of movement mentioned in Chapter IV may be accompanied by some manifestations of volcanic activity

Volcanoes and Earthquakes —It will be noticed that the great earthquakes mentioned in Chapter IV occurred in regions where active or recently extinct volcanoes occur The close association of volcanoes and earthquakes is notorious, and yet it is not quite so complete as many are tempted to think Every region of active volcanoes is subject to earthquake shocks of considerable intensity But the converse is not true, every earthquake region is not at present volcanic Some of the greatest earthquakes of modern times have occurred in non-volcanic regions As instances may be mentioned the great earthquake of Lisbon in 1755, and the very numerous and often violent earthquakes of North-Western India[1] These are far from any region of modern volcanic activity The subject is mentioned here in connection with the distribution of volcanoes, and their association with areas of movement in the earth's crust The close study of the fundamental relation between the two phenomena belongs to the science of geology

[1] The terrible earthquake at Quetta in June 1935 destroyed the town and caused the death of more than 27,000 people

Minor Volcanic Accumulations.—*Mud-Volcanoes.*—Hot water containing much mud in suspension is ejected from fissures in many parts of the world. The mud is usually derived either from sedimentary argillaceous rocks or from fine-grained volcanic ash. Small conical hills with a distinct crater may thus be built up. Such mud-volcanoes are found in regions where volcanic activity is supposed to be on the wane. Some examples are—Baku, on the borders of the Caspian Sea, Sicily, Iceland, Central America, New Zealand, and some of the islands of Malaysia. These small "volcanoes" are of little geographical significance, though of great interest in connection with theories of igneous action.

Geysers.—In many regions hot water only is ejected at regular or irregular intervals. This contains dissolved silica and carbonates, and thus deposits of these substances may be formed. A small mound may thus result in which is a funnel or pipe from which the hot water is thrown out. The Great Geyser of Iceland is this type, and the name has been applied to similar hot-water "volcanoes" elsewhere. If the hot water is ejected from linear fissures and not from a funnel or pipe, terraces rather than cones may be formed. The forms of the siliceous sinter deposits or of calcareous tufa may obviously be most varied. Those of the Yellowstone Park, in North America, and the once famous terraces of North Island, New Zealand, are good examples. The most famous geyser regions are Iceland, Yellowstone Park, and North Island, New Zealand, with others in various parts of the world. Even the valley of the Rhine possesses a small geyser. These deposits are, again, of little geographical importance, but the hot springs from which they are derived throw light on the physics of volcanic action.

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Note on Other Fissure Lavas

Other lavas which are ascribed to fissure eruptions have been described in recent years The Stormberg lavas of Cape of Good Hope Province and Basutoland occupy an area roughly 350 miles long by 150 wide, these lavas are of early Mesozoic age Of approximately the same age are some immense lava fields of South America, which are said to cover an area of 300,000 sq miles, and to have an average thickness of 1000 ft. (See *Ency Brit*, 13th edition, vol ii)

CHAPTER III

CHANGES UPON THE EARTH'S SURFACE EPIGENE ACTION

Two groups of forces and agents are for ever modifying the external form of the lithosphere those depending upon the internal heat of the earth, which are classed as hypogene, and those which act mainly on the surface rocks and are classed as epigene Some of the hypogene forces and their results were considered in Chapter II , in this chapter we shall discuss the chief agents and forces producing changes on the surface We must remember, however, that in separating epigene action from the work of hypogene forces we are making an artificial division, there is considerable interaction among the forces and agents, and some overlap in the results

In extended studies of the changes in progress on the earth's surface it is sometimes thought advisable to consider somewhat separately the forces at work and the agents by which those forces act In the brief summary study which is possible here we shall consider the agents mainly, and the forces will come into the study incidentally For our purpose we take into account the following six agents, remembering all the while that our division is an artificial one wind, rain, percolating and underground water, run-off water and rivers, glaciers and other ice-masses, the seas Let us bear in mind also that, broadly speaking, we may

consider the work of each of these agents under three phases—erosion, transport, deposition—again a more or less artificial separation, employed merely for convenience of study and description

The Work of Wind —Widespread areas on the earth's surface are covered either by grass or by forests, in such regions the action of wind as an agent of denudation cannot be very great It is where large areas of rocks *in situ* or great accumulations of fragmentary rock-material are exposed that wind exercises most influence Three types of regions offer noteworthy examples (*a*) tropical and sub-tropical deserts, (*b*) regions mainly in the middle of continents where there is a long dry season, (*c*) low coast-lands where the retreating tides offer big expanses of sand and where strong and prevalent on-shore winds blow

In tropical deserts the changes of temperature are considerable, and the daily range may be very great Sir A Geikie quotes Dr Livingstone as having experienced such changes that the rock-surfaces were heated up to 137° F during the day and then cooled so rapidly at night that they were unable to bear the contraction without breaking, and sharp angular fragments up to 100 to 200 lb in weight were split off The late G W Lamplugh told the present writer that, on the dry plateaux of Rhodesia he was particularly impressed with the cold nights following the hot days, and that the strains set up by expansion and contraction must cause a good deal of rock-crumbling The wind blows the smaller fragments against the bare rocks and against the larger pieces, and thus, in the long run, much desert sand is made It is easy to understand that there will be accumulations of material of various sizes, from larger angular fragments through sand grains which could be blown by strong winds, down to almost impalpable dust

In a less degree the same kind of action takes place in regions where there are long dry seasons but where the term "desert" cannot properly be applied, much dust is blown by the prevalent winds, which in these regions often blow mainly in the same direction for months on end In such regions sharp cyclonic storms and tornadoes are a common occurrence, and dust-storms, sometimes with enormous whirling columns of dust, are a common feature It must be remembered, too, that in addition to the dust which is produced in the region itself from the waste of its own rocks, there may be added not inappreciable quantities of volcanic dust and some portion of meteoric dust

On sandy beaches, when the tides recede far out, the sand and dust may temporarily become dry, then they can be blown about Neither the finer *dust* nor the somewhat coarser sand is blown much when it is wet, but coastal sand dunes may be formed from the sand which is exposed and dried between the high tides These are examples of low coastal lands all the world over, where the formation of sand dunes can be seen, and the three phases of wind action illustrated—erosion, transport, and deposition

The Action of Rain—Rain-water always contains some dissolved carbon dioxide and variable, slight traces of other acids which it has absorbed from the atmosphere Its action as a weathering agent (that is, an agent of erosion) is both mechanical and chemical The mechanical action is largely effective in so far as it is allied with wind, for it is wind-driven rain which produces the greatest results One has only to examine such rain-weathered masses as the famous Millstone Grit rocks of Brimham Moor, on the eastern Pennines, near Harrogate, to be convinced of the value of the alliance between wind and rain The winds there

abouts come from a westerly quarter oftener than from the other three main cardinal points, and the rocks in that direction are more strikingly eroded than on the other sides, that is, after allowing for local variations in the structure of these irregularly bedded grits The same teaching is noticed in rain-weathered rocks in many other districts

On the other hand, the chemical action at once appears as the more striking in a limestone region The curiously etched surfaces of the Carboniferous Limestone of the plateau regions of the Pennines, with their irregular channels and ribs of limestone rock, are familiar examples On a much vaster scale are the exposed massive limestones of the Karst of the easter Adriatic region, where the chemical solution of the limestone surface has obviously taken place on a great scale

Curiously enough, the action of rain-water is not always destructive There are many building stones which improve on exposure, especially on those sides which face the rainy quarter One concrete example may be more effective than much general assertion The writer was for many years headmaster of a Grammar School which was situated on the Pennine slopes Additions to the building were found to be necessary, and the western walls of the new portion were built of well-squared Millstone Grit stones For a time the rain was driven in and the colour-washes on the interior walls presented a sorry appearance A local architect of wide experience said, "Oh, that will be all right, the stones will, in time, become rain-proof" And he was right In a few years the rain had hydrated some of the constituents of the rock, and probably some of the calcareous cement had been further hardened by combining with the carbon dioxide in the rain-water.

In any case the walls have become "seasoned" and are now comparatively rain-proof

The Work of Percolating and Underground Water

Ground Water—Three things may happen to the rain that falls on the ground part of it may evaporate and return to the atmosphere, another part may percolate into the soil and underlying rocks, and some may run off into the nearest rill or river or lake, the proportions of each will obviously vary with the weather, the lie of the ground, and the nature of the rocks Let us now follow that which seeps into the ground, which we will speak of as "ground water" throughout Broadly speaking, we may think of the history of ground water under five headings Firstly, a portion of it may be dispersed interstitially and evenly among the particles of porous rocks such as the sandstones, grits, and some limestones, here it may act both chemically and mechanically, the latter being the function which concerns us most in the present study Water disseminated among the particles of rocks is one of the greatest agents of disintegration in nature When water freezes and passes from the liquid to the solid condition there is an increase of volume of, roughly, 9 per cent When this happens each frozen particle of water acts like a tiny wedge, tending to force the rock grains asunder, the effects of this may be seen on the face of any cliff or quarry when the thaw follows a frost fragments of rock may be seen at the foot of the cliff or ready to fall away from the face In hundreds of examples this process happens daily, more especially in spring and autumn, in regions where the daily range of temperature is considerable, after the warming of the exposed rock-surfaces by day there comes the cold night, when the thermometer-reading falls to below freezing point

The second phase of possible mechanical work of ground water is that of acting as a lubricant and helping loosened rock, in small or large masses, to slide down the hill slopes The most spectacular examples are when great landslides or avalanches occur, these are most frequent where beds of porous rock overlie impervious strata, such as massive sandstones overlying clays or shales After a period of rain the porous beds become saturated with water, and the upper surface of the clay or shale becomes lubricated, if the slope be favourable, huge masses of the upper strata may slide down the slippery surface until the edge of the cliff be reached and the masses plunge into the valley or into the sea below, these are among the great catastrophes of nature, when viewed from the human standpoint Many a tourist to the Alps must have seen the great scar left by the famous Goldau landslide, so readily visible from the summit of the Rigi The great calamity took place in 1806, a mass of rock, roughly 3 miles long, 1000 feet wide, and 100 feet in thickness—a huge slab of a water-sodden sedimentary rock—"slid" down the mountain-slope and buried the village of Goldau Even this big landslide was insignificant compared with one which took place in the Pamirs in 1911, there a mass weighing over seven thousand million tons "slid" into the valley below, and buried a village with all its inhabitants The huge bank formed by this landslide is 3 miles long and 2 miles wide, and it dammed up a lake 15 miles long and 900 feet deep (See *Ency Brit*, 13th edition, vol ii) It is not suggested that all landslides have a similar origin, but it will readily be seen what an important part ground water may play under certain circumstances

The third type or phase of the occurrence and work of ground water is best seen in regions of massive lime-

stones, here the action is chiefly chemical The surface rain-water, charged with carbon-dioxide from the atmosphere, finds its way downwards into the underground of the limestone through cracks and master joints In this course of downward flow the feebly acid water gradually acts upon the limestone, forming soluble bi-carbonate of lime, which is carried forward and downward This action, in course of time and under favourable conditions, sometimes assumes majestic proportions The British reader may see it best in his own islands in the limestone region of West Derbyshire, on the Penyghent plateau of the West Riding of Yorkshire, in parts of the Central Plain of Ireland, and in the Cheddar region of the Mendips, and there are many other districts of less extent and intensity of action In some other parts of the world, such as the limestone regions of the western Auvergne in France, the southern Ardennes of Belgium, the Karst country bordering on the eastern Adriatic, parts of Kentucky and Tennessee in the United States, there are fine examples of all this underground action and its results, and one should add that every other continent furnishes equally good illustrations it is one of the widespread operations of nature that is being exemplified

This particular work of underground water has the threefold bearing already mentioned, the circulating water erodes, transports, and deposits An acquaintance with any of the regions mentioned at once shows that there must be an extensive and sometimes complicated underground circulation That such and such a river flows underground for many miles of its course is correct so far as it goes, but it is seldom a full statement of the circumstances, extended observation and a good deal of experiment has shown that there is frequently a complicated circulation in that under-

ground the courses of rivers anastomose with each other, there is considerable give and take, and a river which comes to the light of day is very often not the same stream of water which one might expect it to be at first sight The underground courses, with their tributaries and their offshoots, their caverns, vaults, underground pools, and subterranean waterfalls, are all parts of a complicated circulation

This underground water, as it soaks and drips and flows, dissolves calcium carbonate until it is saturated, then, as circumstances are favourable, it deposits again We may write what happens as below, and read it forwards or backwards

(Calcium carbonate) plus (acid water) gives (Calcium bicarbonate), or, as the chemist would write it

$$CaCO_3 + (H_2O + CO_2) \rightleftarrows Ca(HCO_3)_2$$

The deposited calcium carbonate is the familiar calcareous tufa, and the stalactites and stalagmites of the limestone caves, these clearly represent a solution of limestone at the beginning of the operation, its transference in the "hard" water of the underground streams and seepage, and its deposit elsewhere later on The re-distribution of limestone which thus takes place every year must reach colossal proportions

Limestone caves all over the world, from the famous ones of New South Wales to those of British Columbia, are among the show places of the earth, the results of water action underground under such conditions are readily appreciated and are obviously of great magnitude It is doubtful, however, if these showy results are really as big as those achieved by the almost unobserved, quiet, but continuous seepage which goes on The detrital accumulations of organic fragments of which so many limestones consist are, by this continu-

ous percolation, converted into hard, crystalline limestones, and, in some cases, into marbles, the action is precisely the same in character as in the spectacular results of the Mammoth Cave in Kentucky, the famous Grottoes of Hahn in southern Belgium, or in the noted Adelsberg caves in Carniola, the one is easily seen, the other is the sum of an almost infinite number of microscopic actions

The fourth phase in the history of ground water is in the production of *springs* and *wells* Some of the water which has fallen as rain and which has percolated through the rocks or has run along joints, faults, and bedding planes, reappears at the surface in the form of springs or is brought up by man by means of his borings, aided frequently by the use of pumps This phase of the action of ground water is treated in Chapter XII, and need not be considered more fully here except to point out that immense quantities of mineral and rock substances are redistributed in this way, for every spring brings to the surface and deposits somewhere or carries into the rivers some proportion of dissolved mineral substances In the Artesian wells and other borings made by man this process is intensified, see, for example, the water-softening plants and their sometimes unsightly accumulations of precipitated carbonate of lime which are found in the London Basin

A fifth function of ground water is connected with the support of plant life All plants need and seek water, and those which possess true roots send them down, sometimes to very considerable depths, in search of it The more lowly plants, such as lichens, liverworts, and mosses, are notoriously fond of water, and though they have no true roots they contrive to absorb water from the rocks or soils on which they grow Water alone, even though containing carbon dioxide

and nitrogen compounds derived from the air, needs to contain potash compounds, phosphates, and other mineral substances, to serve as "food" for plant life, and these inorganic mineral substances are obtained by ground water in its passage through and among the rocks This is clearly another way in which ground water collects mineral matter and redistributes it , and this, though not so spectacular, and not at first sight so obvious as the other functions of ground water, is of first-rate importance to man The very possibility of man's existence on the earth depends upon this phase of the work of ground water

The Part played by Rivers—Of the rain that falls on the surface of the ground some runs off immediately to join the nearest rill, river, or lake, obviously this is a very variable amount, depending on the dryness of the atmosphere, the nature of the rocks, the configuration of the ground, and other factors This immediate run-off water joins with water from springs, water from the melting of snows, water from the surface, the under ice and the end of a glacier, and the overflow or outflow of lakes All this water forms the **river**, which flows from higher to lower levels, eventually to a lake or the sea The full study of the work of rivers and of the different types of them would require a book of some length, and all that can be attempted here is a summary, setting out the main facts about the work of rivers in redistributing the materials of the earth's crust and the part they play in fashioning the features of the land

The water of any considerable river has usually come from a variety of sources, and its nature and the composition of its dissolved and suspended constituents is the sum of a series of processes acting on rocks and soils of different composition Some rivers flow over and through hard, metamorphic, or igneous rocks, from

which they can dissolve very little, their water is soft and closely akin to rain-water in composition and properties, other rivers flow over and through rocks which contain soluble constituents such as carbonate of lime, common salt, peaty matter, and other substances, yet other rivers flow through and over clays, loams, finely divided sands, loess, and other similar rocks, and these contribute much suspended matter which a river of moderate velocity can carry from higher to lower lands; as in so many actions in nature there is infinite variety of circumstance

Notwithstanding the variety inherent in river action, there are three things it must do—it erodes, transports, deposits River erosion is one of the great and obvious processes in nature not independent of others, but interdependent on them, and working with them In the nature of things river action must be partly chemical, largely mechanical River water above ground is little different from underground water in its solvent action, especially it attacks limestones, as already explained, or, as some would say, it corrodes its limestone bed Running water acts mechanically, too, very little and very gently when the stream flows slowly, but at a rapid rate and on a big scale when the river is in spate In flood-time the water is dashed against rocks already broken and loosened by frost, and pieces of various sizes are detached, the swollen river uses its own suspended matter, and carries along big masses, which it uses like a battering-ram in its attack on the rocks of the river bank and river gorge The work that rivers can do in this way is enormous, and even that of a single storm-flood may assume immense proportions Every geographer or geologist can quote examples within his own experience at home or abroad Many years ago the writer was much impressed by the action

of a tiny stream which, in ordinary times, comes down from Thorpe Fell to join the Yorkshire Wharfe A child can step across the little beck usually, but one summer day there was what in the Dales is called a cloudburst, there was a very violent thunderstorm, with some hours of torrential rain, the little river became a raging torrent, it carried away a well-made road and a bridge, it dashed down its valley, sweeping away stone fences, and it made a mighty alluvial fan of mixed rock fragments at its point of junction with the river Wharfe Such an event is common enough in the Pennines, and, in fact, in all the British uplands, the observant reader can rarely pass a year without being able to observe one flood of considerable violence, and one such observation is worth many pages of text

One who observes these actions of rivers is sure to be impressed by the big boulders which a river may carry in times of sudden flood, he may notice these big weapons of the river during the flood itself, when the spate is over he may see them scattered over the land where the river overflowed He usually finds it difficult to believe that rivers can carry along such big stones, but Hopkins (the famous mathematician), long ago, taught physical geographers that the capacity of transport of a river increases as the sixth power of its current velocity, thus, if the velocity is doubled, the motive power becomes 2^6 or 64 times greater, and if it is trebled the power is increased 3^6 or 729 times It is no wonder that a river which is at all subject to floods eats into its banks, cuts away rocky cliffs, and forms such familiar features as pot-holes, gorges, rapids, and waterfalls, for these are all manifestations of the work of a river acting on rocks of different character, and using as tools the varied fragments which the river may have gathered in its course over different rocks

The work of a river thus supplements the work of wind, rain, and frost Like them it breaks down and destroys The chemical action of a river is called corrosion by some writers, and for the mechanical action of the river, armed with its tools of rock fragments, the word corrasion is often used While not objecting to the use of these terms, the present writer feels that there is a tendency to multiply such technical terms unnecessarily

The material eroded by wind, rain, frost, glaciers, in the uplands of the river basin, is gradually, for the most part, collected by the river The work of the upper or mountain part of the river is mainly this varied erosion, whether it be mechanical or chemical, and theoretically the river has now received its load of eroded material In the old, and somewhat mechanical concept of a river, which was long taught in schools, three parts were usually recognised (1) the Upper, Mountain Track, where the work is chiefly erosion, (2) the Middle, Valley Track, where the work is essentially transport, (3) the Lower, or Plain Track, where the function is mainly deposition This has, no doubt, been a useful, but it was a thoroughly artificial classification, and it should be used only in a most general sense, it fits some rivers tolerably well, many other rivers not at all It seldom fits a river, such as, for example, the Danube, which is a compound river system and not a river in any simple genetic scheme

At any rate, one of the three obvious functions of a river is that of transport, and here again there is a great variety of circumstance a few rivers carry little load, either in solution or in suspension, except the latter in times of flood, other rivers carry much peaty matter in solution, and a little in suspension, but on the whole their water is remarkably pure, many a

river in a limestone region looks pure and clear, but its water is hard from the presence of dissolved bicarbonate of lime, and, on the other hand, some rivers carry much material in suspension, usually consisting of finely divided clay To carry this dissolved material downward, to the lowland plain, to the lake, or to the sea finally, is a chief function of a river To all the matter thus so obviously transported by a river we must not forget to add the loose stones or heavier fine sediment lying on the bed of the river which are always being pushed downward and onward by the current Go into an upland region and notice the banks of stones which are usually present in the bends of the river, go down the river and observe again, notice how the stones become less and less angular, and generally smaller, as the river leaves its upland region, transport and erosion (corrasion) are here going on almost *pari passu*

Now the river approaches its lowland course, the Plain Track of some geographers Here is little erosion, but much deposition The river in the plain overflows from time to time, due to storm rain or melting snow, or seasonal rains, as the case may be, there is again almost infinite variety of circumstance, and to generalise too much or too closely makes the description artificial Some rivers in their plains vary in volume from nothing up to raging floods that cover the plain for immense stretches, other rivers do not vary a great deal, one or more feeders may be in flood while other feeders are contributing only a dry-season's flow Many a river has a long lowland course, through a stretch of almost flat land, here it usually meanders, forms raised banks or levees, ox-bow or cut-off lakes, marshy lagoons, and probably ends in a true delta, with distributaries and delta lakes Another river may have little of this true

lowland track, and no true delta Compare, for example, the Mississippi and the St Lawrence in this respect, or among British rivers compare the Tay and the Trent the fundamental differences are obvious

Many a river has more than one lowland track, and in more than one part of its course produces most of the features of a true lowland river Compare, for example, the Rhine from Strasbourg to Mainz, or, more especially, the part between Mannheim and Mainz, with the next part between Mainz and Bonn, after a true "lowland course" in the Middle Rhine the river cuts through a plateau and then begins what is popularly called its lowland course Similarly the Danube, from Budapest to the confluence with the Drave, is a river in an alluvial plain, just as much as it is in the Rumanian plain, this is even more striking in the case of the great feeder, the Theiss On the other hand, the great African river, the Congo, behaves like a lowland river in that immense plain which lies between Stanleyville and the confluence with the Ubangi, the notation Upper or Mountain course, Middle or Valley course, Lower or Plain course, is clearly inadmissible in the case of the Congo Even a comparatively little English river shows the difficulty of the rigid classification The Ribble has a meandering, lowland course south of Horton in Ribblesdale, a second such course south of Giggleswick, a third below Sawley Abbey, and a fourth between Ribchester and Preston All of which shows that the classification of the course of a river into well-defined parts needs to be applied with some discrimination

Rivers are the great collectors and carriers of eroded material—rock-waste from the action of wind, rain, ground water, glaciers, and the river itself The ultimate goal of this river-borne rock-waste is the lowland

on which the river distributes part of its load, the lake which it is gradually filling up, or the shallow sea in which it is forming shallow-water deposits of sand or clay of various degrees of fineness, down to the most impalpable mud Rivers thus, in their threefold function as agents of erosion, transport, and deposition, represent a group of forces, agents, and processes, by which the external form of the earth's surface is for ever being greatly changed

Glaciers and their Work.—In high latitudes and above the " snow line " in other latitudes most of the precipitation falls in the form of snow , if the temperature is low enough and the snowfall big enough, then evaporation and melting cannot keep pace with it and year after year the accumulation continues and glaciers are formed The glacier is to the snowfall what the river is to the rainfall in the warmer regions , the glacier is naturally formed as an ice-stream which moves outwards and downwards from the snow-field , it is a river of ice which moves slowly towards the low ground, according to its own laws As the glacier passes from its snow-field into a warmer region down below the so-called snow-line, it reaches a belt where the temperature is too high for the continued existence of ice, and there the gradual melting roughly keeps pace with the downward movement of the ice-river

Broadly speaking, two kinds of glaciers are formed—(*a*) Alpine or Mountain Valley Glaciers, and (*b*) Continental Glaciers, and as in all Natural History classifications there are transitional and overlap examples which partake of the distinctive characters of the two broad types The valley glacier of the mountains is fed from the snow-field up above , it gradually moves downwards at the rate of a few feet a day, the middle moving faster than the sides, and the top faster than the bottom,

the retardation being due to friction As the glacier moves downwards in its valley it receives from the adjoining hill slopes rock-waste of many kinds, from big rock-falls broken away from crags and pinnacles down to finer material of all grades This fallen waste commonly forms two irregular lines along the sides of the moving glacier, and these are the lateral moraines If two or more glaciers unite—a common occurrence—it is clear that united moraines must be formed, and these are the well-known medial moraines At the end of the glacier, which may be an ill-defined zone, there is an accumulation of this carried debris, looking somewhat like a huge tip of irregular stones, gravel, clay, and sand, this is the end moraine or terminal moraine Under the glacier there is usually a variable accumulation of rock waste of all grades, finely ground material often predominating—all of it being slowly swept forward by the glacier and carried onward by its sub-glacial streams, this is usually called the ground moraine It is obvious that the terminal moraine is the sum, in a broad sense, of the lateral, medial, and sub-glacial moraines In its turn the terminal moraine is carried away by the "issues" of water which come from the surface of the glacier, within it, and especially under it—these forming the river to which most Alpine glaciers give rise

A common characteristic of rivers which come from the melting zone of a glacier, and which represent the drainage of the ice-fields above and the glaciated valley below, is that they are charged with suspended matter, which comes from the rock-waste of the usual agents, rain, frost, sub-glacial river, and perhaps the erosive action of ice-embedded stones This finely-ground suspended material is carried down into the lowlands, to be deposited on flooded meadows, or in a lake through which

the river flows, or carried out to sea; in the sum total it represents a vast amount of rock-waste, and the transference of much rock material from the mountains to the plain, the lake, or the sea. There is a sense in which glacier ice itself may not be capable of much erosion, and it has been said by men who know Alpine glaciers well that even the protective function of such ice must be considerable; but taking the Alpine glacier as a whole, with the action of frost going on all above it and around it, with the inevitable contributions of rock falls, with the action of intra-glacial and sub-glacial streams—looking at it as a great system, as a complex agent—it obviously erodes, transports, and deposits. Glaciers may then be classed among the great natural agents of change and redistribution which are for ever playing their part in moulding anew the face of nature.

Alpine glaciers are readily studied in the Alps, where the very ordinary tourist may see them, cross them, and study them without much difficulty. Others are found in the Caucasus, the Elburz Range, and in the great radiating systems of Central Asia, where great valley glaciers are on a scale commensurate with everything else in that wonderful region. They are met with in the Rocky Mountains, in the Cascade Range, and the Sierra Nevadas of North America, and some of the finest examples are in Alaska. The Andes abounds in them; and they may be studied in the Alps of South Island, New Zealand. The glaciers of Norway and of Iceland are somewhat transitional between Alpine glaciers and continental glaciers—the second great class of these ice-fields, for they are more ice-fields than ice-rivers. Two regions stand out—Greenland and the Antarctic Continent. The ice-sheet of Greenland is 5000 to 7000 feet thick, and covers an area more than

four times the area of the British Isles The ice plateau of Greenland is 10,000 feet high in places, and whatever the real topography of the land may be, we can only guess, for the stupendous ice-sheet buries it completely The important point at present is that the vast Greenland ice-sheet seems to shed itself seawards in all directions and a sort of valley-glaciers of a grand Norwegian type occupy the fiords on the edge of that vast land Here are born many of the icebergs of the North Atlantic, broken off the great mass as it overflows, so to speak, from the great ice-making ground of the vast interior

The Antarctic ice-field is several times greater than that of Greenland, great as is the latter, and the evidence of icebergs and of direct observation proves that the thickness of the great ice-covering is at least a mile, often probably 6000 or 7000 feet, and there is reason to think that it is nearly 2 miles at the edge in some places What its thickness is in the vast interior we can only wonder The icebergs which break off from the ice-fields of the Antarctic Continent are bigger in area, though usually not appearing much higher out of water than those of Greenland The icebergs of the north and those of the south float away into the warmer seas, where they gradually melt, a vast amount of continental debris is thus transferred to the sea bottom, and is not necessarily deposited in shallow seas, as is the case with so much continental waste Iceberg waste has certainly accumulated in the North Atlantic to a depth of many thousand feet, in an ocean area which would be from 12,000 to 18,000 feet deep The warm Gulf Stream in that region is in the act of becoming the North Atlantic Drift, it is gradually distributing its warm water over a wide superficial area, here it is met by the cold currents from Labrador and Greenland, bringing southwards vast numbers of icebergs every year The

result is fairly obvious The icebergs from the northern lands carry much continental debris, this must clearly fall in the region largely where the bergs melt The enormous deposits of clay with rock fragments which were investigated by the late Sir John Murray are the result Here the icebergs are playing their important part in the transference and deposition of eroded material, which once again stands out as a great process of nature which is continually being enacted

The Work of the Sea on the Coasts—The waves of the sea attack the shore-lands, and helped chiefly by tidal streams the three phases of the great compound process are again seen—erosion, transport, deposition The sea interacts with all the other agents in varying degree, with wind, rain, frost, rivers, and glaciers Rain-water percolates the rocks of cliffs which line many shores, frost comes into play, acting through the ground water, and masses of rock are broken off and lie in scattered masses at the foot of the cliffs The waves—either ordinary tidal waves or those driven against the cliffs by strong winds—roll the broken masses of rock against each other and hurl them against the exposed cliff

The waves themselves exert irresistible pressure, during strong gales from the Atlantic the breakers often exert a pressure of over a ton to the square inch, and big rock masses are literally hurled about The waves batter the cliffs with these weapons derived from the rocks themselves, and immense rock damage is often done The natural rocks are thus worn away, and artificial structures, such as sea-walls, docks, and wharves are more or less ruined Many a reader must have stood in wonder as he has seen the destruction brought about by a recent gale, such destruction is common enough on the coasts of Britain, and on all

coasts where man has erected his structures, even in comparatively tideless seas the ruin is often very great

The water of the waves, as it advances up against the rocky cliffs, drives the air and compresses it in the joints and cracks of the rocks If there is an air passage through from cliff face to some safe point slightly away from the edge, the observer may often observe a "blow hole" where the air is driven with great force through the underground passages and spouts out on the landward side somewhere Compressed air helps greatly in the disintegration of the rocks, and the work of this weapon is added to that of the rock masses and the finer sediment which the waves use as a battering-ram

The evidence for, and the results of, coast erosion are among the common things of shore-lands all the world over—in some regions greater than in others, as may be expected In the British Isles there are so many traditions and historical records of lost towns, ports which have disappeared, churches, castles, and other buildings that have fallen into the sea, that many British people have felt uneasy at the greatness and the ubiquity of the loss A Royal Commission investigated the subject in the first decade of the present century, and issued its report in 1907 This report reassured us considerably, as it showed that the gain by natural deposition and the reclamation of land by man more than made good the loss by erosion

Notwithstanding the findings of the Commission the evidences of erosion are very widespread on the British coasts, and the results of that erosion are responsible for some of the wildest and grandest of the coast scenery Out of thousands of possible illustrations one may quote the Armed Knights of Lands End, the Stacks of Holyhead, Carrick-a-Rede in north-eastern Ireland, the Old Man of Hoy, the Farne Islands, the Seven Sisters of

Beachy Head, and the Needles of the Isle of Wight, as well-known and excellent examples Many of the wildest and most famous of the caves and the coves of our coasts owe their formation to frost and rain in addition to marine erosion, but they are none the less grand and impressive for all that

And what becomes of this eroded material? The findings of the Royal Commission answered the question statistically, but of course many of the broad facts had long been known Tidal streams or drifts are a common phenomenon on the coasts of tidal seas, and these cause the disintegrated coastal waste to be drifted gradually to some estuary or other region where deposition may readily take place For example, while the coast of Holderness has been losing for centuries, and while Ravenspur has been washed away inside Spurn Point, only a little farther up the Humber estuary there has been considerable gain of land Hedon, an old port, has been silted up and the new land, appropriately named Sunk Island, has been formed No doubt rock-waste brought down by the Yorkshire Ouse and the Trent has combined with coastal waste to supply the material out of which the new land has been built Many other parts of the British coasts, and shore lands all over the world, provide equally good examples In short, the waves and the tidal streams and other shore currents carry on the same work which we have found the other agents to be for ever doing—eroding, transporting, and depositing, fashioning a new landscape, and doing for the surface of the lithosphere the work that is complementary to that of the hypogene forces

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CHAPTER IV

LAND-FORMS

THE rocks of which the earth's crust is composed seldom remain in the unaltered condition or in their original position The strata of the sedimentary rocks are rarely horizontal, most of them having been bent, folded, and fractured These changes in position and relationship are intimately associated with the various types of land-relief existing on the earth's surface *Land-forms* are almost infinite in their variety, and grade into each other so imperceptibly that there is much difficulty in classifying them, and there is, as yet, no really satisfactory classification We shall attempt an arrangement of convenience, from a geographical point of view, in this and the succeeding chapters

MOVEMENTS OF THE EARTH'S CRUST

It is necessary to realise, at the outset, that the earth's crust is in an unstable condition , even those regions which seem to be the most stable being subject to frequent, though minute, disturbances The region of the British Isles is popularly regarded as typically stable, but modern refined methods of observation show that it is disturbed by very frequent small earth-tremors Many parts of the British Isles are subject to slight earthquakes These seem to be most frequent near the great boundary fault, or line of dislocation, which separates the Grampian Highlands from the Midland Valley of Scotland. It has been shown that

earth-shocks of very slight intensity may occur there at the rate of two or three per day

In many parts of the world earthquakes of greater intensity are of frequent occurrence, and their effects are too obvious and notorious to need emphasis here It may, however, be pointed out that the *geographical* effects of even the greatest earthquakes are usually very slight They produce a great impression upon the human mind, and are very destructive of man's work, but they usually change the surface of the earth but little Occasionally greater effects are produced, as in the famous example studied by Charles Darwin in Chile in 1835, where he showed that the coast of that unstable region had been relatively raised to the extent of 8 or 10 feet In the destructive earthquake of San Francisco in 1906 there was some vertical and horizontal displacement of the ground along a line of fault In the Alaskan earthquake of 1899 the beach was raised in places by over 40 feet, and barnacles could be seen, several years after the shock, still attached to the rocks far above high-water mark Again, in the earthquake of South Calabria in December 1908 there was measurable displacement of the surface To anticipate somewhat, it may be remarked that the area affected by the last-mentioned earthquake lies on the inner or concave side of a great curve of "fold-mountains" The earth's crust inside this curve is, in all probability, still sinking, and the Tyrrhenian deep sea is a recently foundered part The rim of this sinking part is, therefore, subject to frequent earthquakes This is frequently the case on the inner or concave side of such fold-mountain curves [1]

There are movements going on in the earth's crust which are not so obvious as those connected with the

[1] See note on p 83

greater earthquakes, but which are much wider in scope, and affect larger areas These slow movements have long been studied in Sweden where the pioneer naturalists, Celsius and Linnæus, made their now classic observations To the north of Stockholm the land is rising at the rate of at least 2 or 3 feet per century, in Scania (Southern Sweden) the land is sinking probably at rather more variable rates In the north of Norway the land must have risen at least some hundreds of feet in Pleistocene and recent times Similar evidence has now been accumulated from many parts of the world, and there is not the least doubt that great areas of the crust are sinking, and in other regions great areas are relatively rising The cause of these great crustal movements is not quite clear; it has been held that it is connected with a secular cooling of the earth, but there is now considerable doubt whether that will furnish a satisfactory explanation The facts are clear, the full explanation is a matter for future research, and its further discussion outside the scope of this book

Two broad, general types of crustal movements are now recognised, namely, those which act in a *radial* direction and those which act in a *tangential* direction The former cause elevation or depression of large areas, that is, movements away from or towards the centre of the earth These movements have been termed *continent-building*, but the term is open to considerable objection The latter act in a direction more or less parallel to the earth's surface, and are often known as *mountain-building* movements The two types of movement are not independent of each other, on the contrary, they usually seem to have been closely associated They produce, respectively, some of the most important and well-defined of the land-forms

Folded or Alpine Mountains —The most conspicuous features in the structure of most of the continents are long lines of mountains composed of intensely folded strata, and carved by the forces of erosion into the sierra-like forms so familiar in the Alps and other mountain ranges of Southern Europe As the Alps have been studied with great thoroughness by both geologists and geographers, and as their structure seems to be quite typical, the descriptive name, "Alpine mountains," is often applied to such mountain chains everywhere

Such mountain ranges are mainly the result of forces acting in a tangential direction, and the first apparent result of such forces is the production of folds in the strata Earth-folds may be illustrated in a very effective and simple manner by placing weights on a thick, heavy tablecloth and then pushing the latter across the surface of the table According to the nature of the cloth, the intensity of the thrusting force, and the resistance offered, the folds will vary from quite simple ones to those of a complex character

The simplest folds in the rocks are those in which the strata are bent fairly equally into the form of an arch or trough, known in geology as the *anticline* and *syncline* The south-eastern quadrant of England furnishes excellent illustrations of these simpler folds Let an observer travel from Aylesbury to London and then from London to Brighton, and let him observe the nature and position of the rocks He will, in the course of his journey, meet with three lines of low chalk hills The first are the Chiltern Hills, these are chalk downs presenting a relatively sharp face to the north-west and a gentler slope towards London The latter is the "dip-slope," and the strata dip or slope at a low angle towards the Thames Basin At Watford or

Rickmansworth the chalk surface is left behind and the Tertiary strata of the London or Thames Basin begin From this point to near Croydon the Tertiary rocks continue at the surface, though the chalk has been proved to occur below them in numerous borings

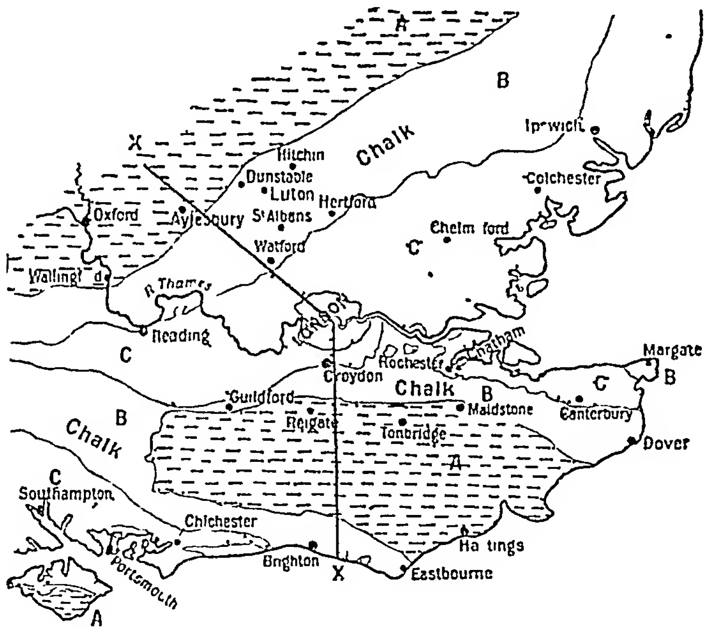


FIG 5 —A GEOLOGICAL MAP OF THE SOUTH EASTERN QUADRANT OF ENGLAND

A. Rocks older than the Chalk B Chalk of Chilterns, North Downs, etc C Tertiary strata, newer than the Chalk X——X Line of section shown in Fig 6

for water The chalk reappears at the surface in the North Downs, these hills, however, having the dip-slope towards the north and the sharper cut edge (called the escarpment face) towards the south At Reigate or Red Hill strata older than the chalk are seen, and these continue across the Weald until the chalk re-appears in the South Downs In these hills the sharp

edge faces the north and the gentler dip-slope is toward the English Channel The observer has thus passed over a downfold or syncline, and an arch or anticline, the summit of which has been removed by long-continued denudation The Chilterns, the London Basin, the North Downs, the Weald, and the South Downs thus form parts of a great earth-wave consisting of an anticline and a syncline This wave represents a distant part of the great "Alpine Storm" of Europe The relations of these rocks of South-Eastern England are shown

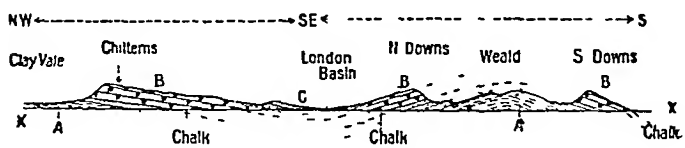


FIG 6 —A SECTION FROM NEAR AYLESBURY TO LONDON, AND TO BRIGHTON

A. Rocks older than the Chalk B Chalk of Chilterns, North Downs, etc C Tertiary strata, newer than the Chalk (*See* Map, Fig 5)

in the geological map and diagrammatic section (Figs 5 and 6), which should be carefully studied.

Some regions show much more complex folding than that of the Thames Basin and the Weald The Jura Mountains on the Franco-Swiss border consist of Mesozoic rocks thrown into a sharp succession of anticlines and synclines, with much faulting or dislocation of the strata The same "Alpine Storm" which produced the gentle folding of South-Eastern England displayed greater intensity in the Jura region, and produced the more complicated folding

Very much more complex, however, are the earth-storm effects in the Alps, where there is much compli

cated overfolding and often displacement of strata by huge thrusts Here the tangential pressure-forces have acted from one side more than from the other, hence the folding produced is of a pronounced asymmetric character Not only have great folds been produced, but they have been flattened out afterwards, and portions have often been detached, and older rocks have been pushed over newer ones

The Alps consist for the most part of rocks of later Palæozoic, Mesozoic, and early Cainozoic Age The great tangential folding movements combined with some vertical uplift took place in Middle Cainozoic times chiefly, and were so intense that the shortening of the arc of the earth's crust has been variously estimated at from 70 to 100 miles

Evidence of this complex folding of the strata may be readily seen in many parts of the Alps Standing on the northern slopes of the Dent du Midi and looking across the Rhone Valley to the mighty walls of the Dent de Morcles and the Diablerets beyond, the observer may see immense folds involving thousands of feet of strata The mountain walls have been trenched by vast rock-falls, and on the gigantic, precipitous rock-faces the great bends of the Mesozoic rocks may be seen miles away (*see* Fig 7) At Martigny, in the Gorge of the Lizerne, and in the Trient Valley, similar evidences of stupendous folding may be seen

A most interesting district for the study of Alpine folding is the neighbourhood of Lake Lucerne In Fig 8 a study of a well-known section is given, in which the complex folding of the Mesozoic and Cainozoic rocks, forming the Burgenstock and the Musen Alp, are seen to have reached the stage of complete inversion The *older* Trias and Jura are folded over on top of the *newer* Cretaceous and Eocene, and to the left of the

section the whole vast system of folded rocks is thrust against and partly over the more recent Miocene conglomerate

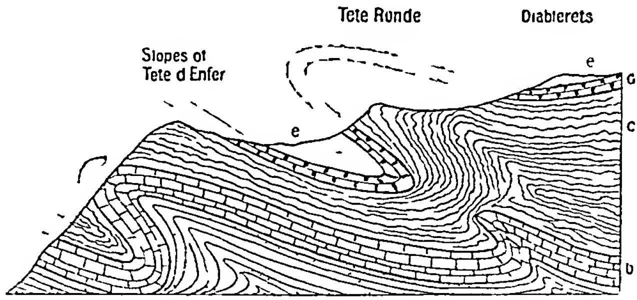


FIG 7 —DIAGRAMMATIC SECTION THROUGH THE ROCKS ON THE SOUTHERN FACE OF THE DIABLERETS, WESTERN END OF THE BERNESE OBERLAND, AND OVERLOOKING THE RHONE VALLEY

a. Upper Triassic Rocks *b* Lower Jurassic Rocks *c* Lower Cretaceous Rocks *d* Upper Cretaceous Rocks *e* Eocene Rocks The Eocene Rocks are folded in, between the older Lower Cretaceous Rocks

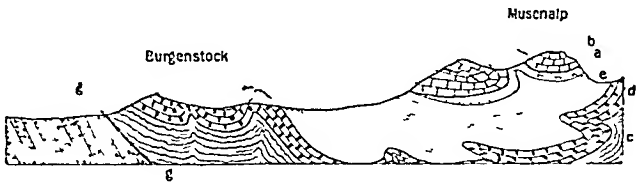


FIG 8 —A DIAGRAMMATIC SECTION THROUGH THE ROCKS OF THE BURGENSTOCK AND MUSEN ALP, NEAR LAKE LUCERNE

a Triassic Rocks *b* Jurassic Rocks *c* Lower Cretaceous Rocks *d* Upper Cretaceous Rocks *e* Eocene Rocks *f* Miocene Conglomerate (Nagelfluh) The older rocks, *a*, *b*, have been folded over above the newer Eocene, *e* The whole of the Mesozoic and Lower Tertiary rocks have been thrust over the newest rocks of the section, the Miocene A "thrust plane" is shown at *g* *g*

Uplift and folding constitute one phase in Alpine history, erosion and denudation a second phase Erosion

proceeds with great rapidity in these high mountains. One only needs to see the state of Alpine torrents after a rainstorm on the mountains, or to notice the evidence of rock-falls, which occur so frequently, to realise how rapid is the process of erosion, and how quickly the great masses of folded rocks are being carved into ranges of contrasted peaks and deep valleys, and the whole system reduced to a lower level.

The rapid erosion gives the *sierra* character, with the series of sharp peaks so characteristic of Alpine ranges. The descriptive Spanish word, "*sierra*"[1] is, therefore, frequently used to describe the profile of Alpine ranges, of which the Sierra Nevada range in Southern Spain is another good example. There is a succession of names in the Alps which bears eloquent testimony to their sierra character. In the Mont Blanc region are the famous *Aiguilles* (Fr. *aiguille*, needle); examples:—Aiguille Rouge, Aiguille Verte, Aiguille du Dru. Among the mountains adjoining the Rhone Valley the name *dent* (Fr. *dent*, tooth) is of frequent occurrence; examples:—Dent du Midi, Dent de Morcles, Dent Blanche. In the Pennine Alps and the Bernese Oberland are the famous *horns* (Teutonic, *horn*), such as the Matterhorn, Wetterhorn, Weisshorn, Schreckhorn, and a score of others. In Canton Glarus, *piz* (akin to the northern spitz, pointed peak) occurs over and over again; examples:—Piz Linard, Piz Bernina, etc.

Alpine ranges are notched by valleys of greater or lesser depth, which provide access to the middle of the chains. It often happens that two river-valleys from opposite sides have cut back so far that a low notch results, and a *pass* is formed. From end to end of the Alps passes occur which are famous as the routes across which, in peace and in war, men have traversed

[1] Sierra: Spanish, *saw-like*, from Latin, *serra*, a saw.

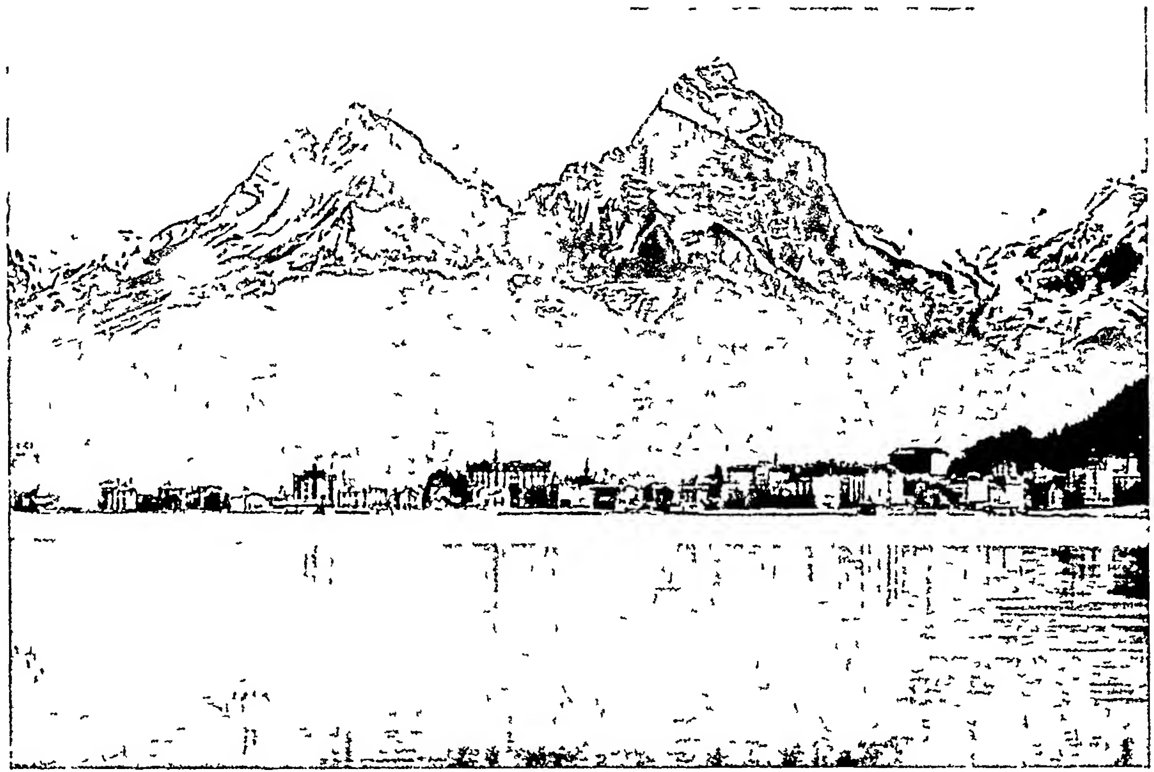


Plate IV —Mythen, overlooking Lake Lucerne

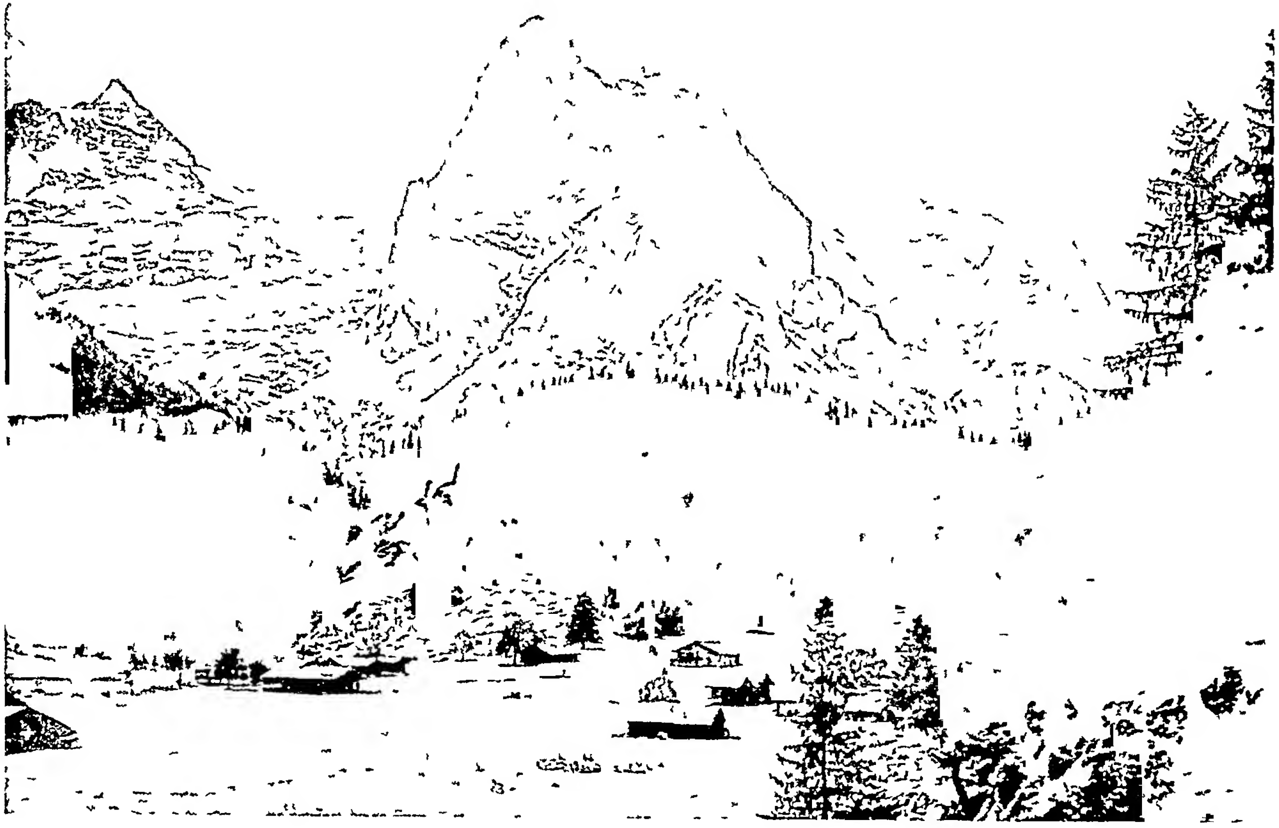


Plate V —Rosenlaui, Wellhorn, and Wetterhorn (Bernese Oberland)

the mighty ranges The more famous passes sometimes determine the divisions of the Alps as used by the geographers, for example, the Pennine Alps are usually held to extend from the Great St Bernard Pass to the Simplon Pass, and the Lepontine Alps from the Simplon Pass to the group of passes near the head of the Hinter Rhine Similarly, in other great ranges of Alpine type, there are passes, higher or lower, as the case may be Most of the passes in the high Alps are between 6000 feet and 8000 feet above sea-level, those in the lower Carpathian range are between 1500 feet and 3000 feet above sea-level, those of the mighty Himalaya are above 15,000 feet and at least one of over 20,000 feet above sea-level is in fairly regular use

Young mountain ranges of Alpine type occur in all the continents except Australia, they are characterised by the same general features—rock-folding of a complex character, notching by erosion into sierra lines of sharp contrast, with means of communication across passes of varying height and difficulty Each great system has its own individual characteristics, as may be expected For example, in some ranges there are active volcanoes which introduce another element into the structure of the chain Few recently active volcanoes occur in the European Alpine system strictly so-called, but in the Caucasus and Elburz ranges, which link the lesser European system to the greater one of Asia, there are volcanoes which are dormant or which have become extinct in comparatively recent times

The Eurasian system includes the following well-defined ranges

Pyrenees, Alps, Carpathians, Balkans

Sierra Nevada, Atlas (N Africa), Apennines

Dinaric Alps, Pindus Mountains, Mountains of Crete, Taurus, and Anti-Taurus

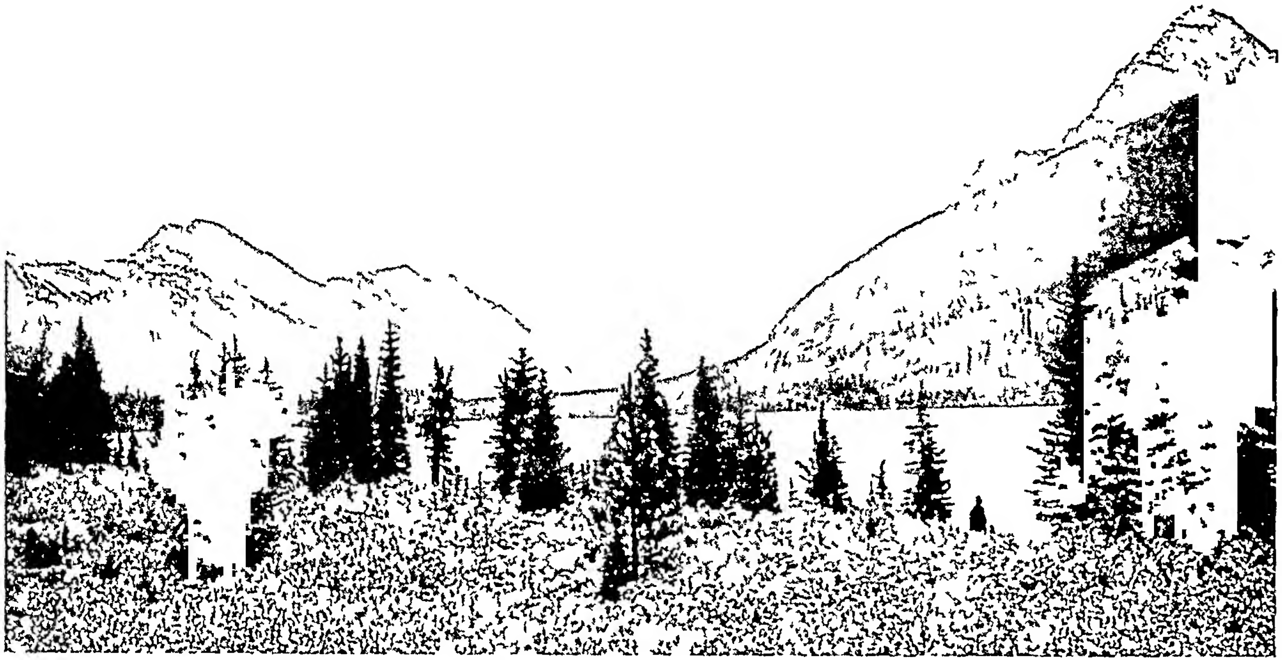
Mountains of Southern Crimea, Caucasus, Kopet Dagh, Mountains of Khorassan, Hindu Kush
Pontic Mountains, Armenian Mountains, Elburz Mountains
Kurdistan Mountains, Zagros Mountains
Pamirs, Sulaiman Mountains, Karakorum, Himalaya, Kuen-Lun, Thian Shan, Arakan Yoma, Patkoi Mountains.

The student should study this great system of fold-mountains on a good orographical map

In Eastern Asia, in the islands of Malaysia, and in New Zealand there are great loops or festoons of volcanic mountainous islands which are probably an immense Alpine system, large parts of which are below sea-level The mountains of Kamchatka, of Japan, of Sumatra and Java are quite Alpine in character, though studded with numerous active volcanoes The New Zealand Alps possess the typical features of an Alpine range, and the name is well-deserved In North America a triple line of fold-mountains extends from Alaska in the north-west to the Mexican plateau The Rocky Mountains form the eastern rampart of the great elevated region of Western North America On the Pacific side of this western system of highlands are the coast-ranges overlooking the deep ocean, and an inner system of which the Sierra Nevada and Cascade ranges are the best known In Mexico, Central America, and the West Indies, is a system somewhat comparable in form to that of Eastern Asia The general trend of the mountain-lines is here east and west, with concentric curves or festoons of volcanic mountains and mountainous islands The triple line of the Cordilleras of the Andes in South America corresponds generally with that of the North American

[*By courtesy of the High Commissioner for New Zealand*

PLATE VI.—"THE REMARKABLES" ALPINE MOUNTAINS, SOUTH ISLAND, NEW ZEALAND



[By courtesy of the High Commissioner for Canada

PLATE VII.—VIEW OF THE ROCKY MOUNTAINS IN ALBERTA

ranges, but while the latter widen out to more than 1000 miles in their middle part, the South American system barely reaches half that width in its widest part

Older Mountain Ranges—It is clear from the consideration of Alpine mountains that they are prominent features in the structure of the continents The ranges enumerated in the preceding section have acquired their present general form and structure in the later geological periods Most of them date from Cainozoic times It seems reasonable to suppose that similar folding, followed by an erosion phase, must have occurred in the older geological periods, and the wrecks of older folded mountains may reasonably be expected among the various land masses As a matter of fact all the continents show traces of older continents, and the grain of old mountain ranges may often be seen partly obliterated by the more recent mountain-building movements This subject may be illustrated by examples

Caledonian Range of North-West Europe

In the Devonian period a vast continent stretched across what is now the North Atlantic and most of Northern Europe Across this northern continent tangential pressure in the earth's crust produced an old Alpine range, just as pressure in the crust produced the present Alps in Tertiary times This ancient range stretched at least from the west of Ireland to the north-east of Scandinavia, and was probably as extensive as the modern Himalayas The long-continued erosion phase began towards the close of the Devonian period and was continued through the Carboniferous and later geological periods The erosion of its plutonic and metamorphic rocks, and probably of its sediments,

provided, during the Carboniferous period, the material for the formation of the immense deposits of the Millstone Grit of the north of England Since that time the range has been subject to many geological "accidents," and now only its worn-down and broken relics are left as the Highlands of north-west Ireland, the Highlands of Scotland, and the plateau-highlands of Scandinavia

Armorican and Variscan Mountain Fragments of Europe

Relics of ancient folded mountains of about Permo-Triassic Age exist in Central and Western Europe The great mountain-building movements of those times have been called Hercynian The ranges then formed were probably not so complex as the more modern Alps, but they were mighty systems The denuded and broken fragments now existing form the series of low mountains of middle and western Europe, including the Riesen, Erz, Fichtel, Thuringer, Harz, and Rhon mountains, the Westerwald, Taunus, Black Forest, and Vosges These fragments have been named the Variscan mountains The Hunsruck, Eifel, Ardennes, the Auvergne of Central France, the rocky highlands of the Cotentin, Brittany, Devon and Cornwall, and Southern Ireland, with possibly the Meseta of Spain—have been named the Armorican Mountains These Armorican highlands may be a little older than the Variscan highlands Both of them suffered erosion and denudation during the long Mesozoic and Cainozoic eras, and both took part in resisting and giving direction to the Alpine earth-storm The denuded and broken fragments stand in the modern continent as reminders of a Europe long since passed away These residual blocks of the Armorican and Variscan systems lead us naturally to a consideration of "Block Mountains"

Block Mountains—These are portions of the earth's

crust which have been uplifted bodily above the surrounding country, or which have been left standing when adjacent blocks have subsided A classic instance, and one of the best possible illustrations, is furnished by the old blocks of the Vosges and Black Forest, with the depressed valley of the middle Rhine between them,—the "Rift Valley" of the Rhine The relation of these crust-blocks will be best understood from a brief history of the whole region At the end of the Jurassic period the eroded, irregular surface of the old Variscan mountains had been depressed below sea-level and was covered with a thick mantle of Mesozoic rocks This stage is represented in the diagrammatic section, Fig 9A During the earlier Tertiary Alpine movements there was depression of the whole region, involving not only the Mesozoic strata but also the underlying granites, gneisses, and Palæozoic sediments A middle-European sea flowed over a sunken part in the Oligocene period, on the floor of which were deposited the marine Oligocene strata now found under the covering of the Rift Valley The section (Fig 9B) represents the condition of things at the end of the phase

The great folding-movements of the Alps took place, as already stated, in Miocene times, and the region under consideration was again subjected to disturbance Two parallel lines of faults were initiated, which let down the Rhine rift valley between the *horsts*[1] of the

[1] A *horst* is a crust-block left standing during the subsidence of the adjoining region more or less on two sides The following are well-known examples The Grampian Highlands of Scotland bounded by the fault line of Glenmore and the Highland boundary fault, the Thuringer Wald, the small plateau of Morvan in Central France, the mass of Sinai with the sunken Red Sea on one side and the Gulf of Akaba on the other, and Korea, between the sunken areas of the Yellow Sea and Japan Sea

Vosges and Black Forest Subsequent erosion removed most of the Mesozoic strata from the higher

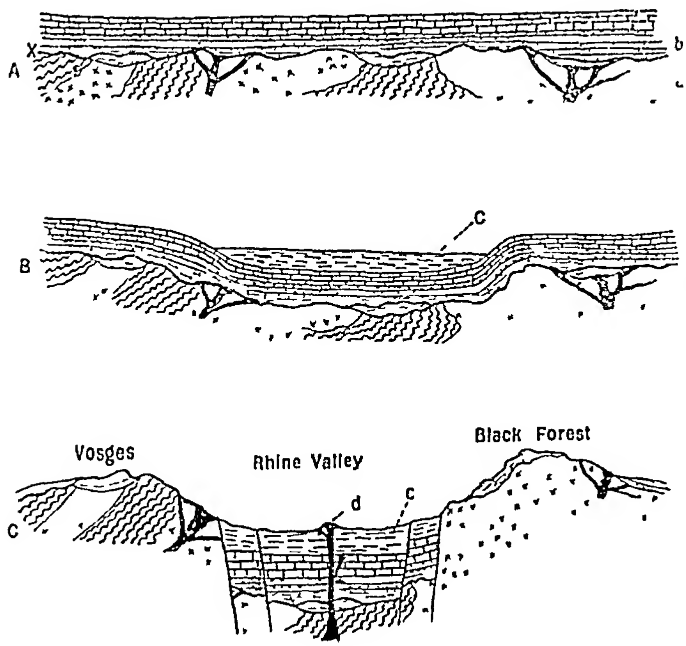


Fig 9 A, B, C—Diagrammatic Transverse Sections across the Rhine Rift-Valley and the Adjacent Crust-Blocks at different Geological Periods.

A At the end of the Jurassic period B. At the beginning of the Miocene period before the great "Alpine Storm" occurred C At the present time

a Palæozoic, and older Igneous, and Metamorphic rocks *b* Mesozoic rocks *c* Oligocene rocks *d* Later Igneous rocks forming the Kaiserstuhl A pre-Mesozoic land-surface is shown at X X in Fig 9A

parts of the region This final stage is represented by the section, Fig 9C

The Vosges and Black Forest thus stand up as Block Mountains with the rift-valley of the Rhine between them The Feldberg of the Black Forest is 4900 feet high,

the Belchen of the Vosges 4700 feet, the rift valley has an average elevation of about 600 feet The Rhine flows through a plain of recent deposits, at Basle at a height of 870 feet, near Strassburg, of 470 feet, at Mannheim, of 300 feet

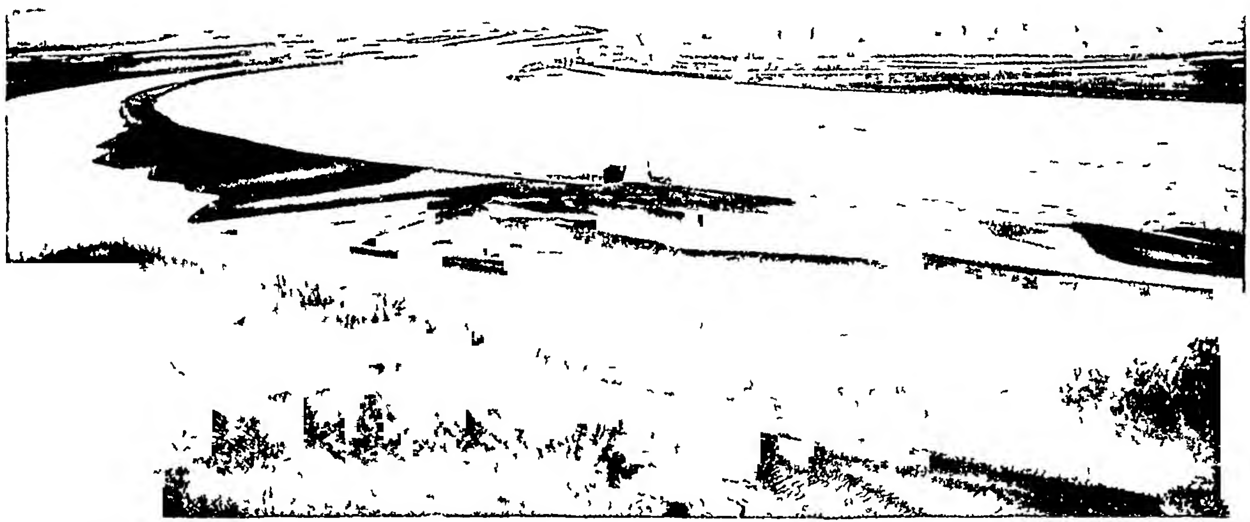
The other parts of the Variscan and Armorican ranges were broken up in various ways Deep and long fractures cut the ranges into blocks which rose or fell independently, and thus the old fragments stand up as the block mountains of middle and western Europe Many of these are now worn into the condition of a plateau, especially is this the case with the Belgian Ardennes and the Eifel

Plateaux—From the consideration of block mountains we may now pass to the closely related areas of uplift, generally of greater extent and usually of more even surface, known as *Plateaux* It has already been mentioned that movements of displacement of large portions of the earth's crust, from or towards the centre of the earth (radial movements), are interdependent with the tangential movements which produce folded mountains At the time of the folding which produced the younger Eurasian mountains, for example, great areas of depression were formed on the inner or concave side of the mountain curves Thus were produced the depression of the Hungarian Sea, afterwards to be filled with sediments and to become the Hungarian Plain, the Adriatic Sea, a part of which has already been filled with sediments to form the Plain of Lombardy, and the Tyrrhenian Deep, enclosed between Italy, Sicily, and Sardinia During the same long period *uplift* of great masses took place, chiefly earth-blocks already in existence, some of which were unevenly tilted and frequently broken in the process The Meseta of Spain, the Auvergne plateau, and the

lozenge-shaped plateau of Bohemia, with its irregular surface, then took on their modern form

In Asia, the plateaux, of which the positions and relations were then determined, are on a stupendous scale The fold-mountains of that continent are intimately related to the areas of elevation and depression of large earth-blocks, as in the case of Europe The plateau of Anatolia or Asia Minor is bounded by the Pontic Mountains on the north and by the Taurus and Anti-Taurus Mountains in the south and south-east The plateau of Iran is surrounded by Alpine ranges,—Kopet Dagh, Hindu Kush, Sulaiman Mountains, Zagros Mountains, Kurdistan Mountains, and Elburz Mountains The greatest and highest plateau in the world,—that of Thibet,—has round it the Pamirs, the Karakorum, the Himalaya and Trans-Himalaya, and the Kuen Lun and Thian Shan mountain ranges, whose length and height are commensurate with the mighty crust-block they surround The Tarim basin is a plateau of lesser elevation among the enormous masses of mid-Asia Situated almost in the middle of the continent, and almost surrounded by mighty walls of Alpine mountains, it is a *relative* depression with an average elevation of about three thousand feet above sea-level

The Arabian plateau and the Deccan of India are not so obviously related to any lines of Alpine mountains They are probably part of an ancient continent which included much of the present Africa and Australia, as well as the semi-detached parts of Southern Asia This ancient continent seems to have been remarkably free from such lines of sharp folding as are characteristic of Eurasia and the Americas, hence its relics are plateaux which have been the theatre of long-continued denudation, and subject to many accidents of earth-movement



[Reproduced from "Central Asia," by Dr Sven Hedin

PLATE VIII — THE TARIM RIVER, CENTRAL ASIA: AN "INTERNAL DRAINAGE" RIVER

since Permian or Triassic times The recognisable parts of this ancient continent are the plateaux-regions of Africa, Arabia, the Deccan, and Australia

The great plateaux and basins of North America are closely related to the long lines of Alpine mountains in much the same way as those of Eurasia are to the similar mountains of the Old World An orographical map of North America shows a succession of plateaux and elevated basins between the Rocky Mountains and the western coast-ranges These plateaux are mainly large blocks of the earth's crust bounded by faults or by simple folds The Mexican and Colorado plateaux, the Utah basin, the Columbia, Frazer, and Yukon plateaux are structural divisions which the student will readily understand

In South America the western mountain-system is threefold as in North America, but its parallel ranges are too close together to allow of table-lands as large as those of the northern continent In latitude 18° S, Lake Titicaca occupies the same relative position with respect to the mountains of South America that the Great Salt Lake occupies in North America

It may be mentioned here that there are immense plateaux of a different type in North America east of the Rocky Mountains These vast plateaux slope gradually from heights of over 6000 feet to the comparatively low alluvial plains in the middle of the continent, and present monotonous stretches of prairie dissected by the great rivers which drain to Hudson Bay and the Gulf of Mexico The "Bad Lands" of Dakota consist of plateaux-blocks deeply scored by the White River and its tributaries The rivers have cut so deeply that some portions of the dissected regions are almost inaccessible These plateaux are related, in all except their elevation to the plains of alluvium and recent sedimentation to be

discussed later, more than to the crust-blocks already described They are mentioned here in order to emphasise again the difficulty of establishing hard-and-fast divisions of land-forms

Mountain-rims of Plateaux—Plateaux of the crust-block type have frequently elevated, scarped edges, which from neighbouring lowlands appear as considerable mountain-chains, but which present only a moderate elevation when seen from the surface of the plateaux The following well-known examples may be quoted the Cevennes 'range' is the eastern rim of the tilted Auvergne crust-block, the Sierra Morena is the southern edge of the Meseta of Spain, the Erz Gebirge and Riesen Gebirge form the northern edge of the Bohemian crust-block plateau, and the Western Ghats form the sharp mountainous western edge of the Deccan of India

Fractured Crust-blocks—The fracturing of the Variscan and Armorican mountain-systems prepares us for the frequent fracturing of the residual fragments Such fracture-lines are of frequent occurrence, and are geological accidents which have produced important geographical consequences The lozenge-shaped plateau-massif of Bohemia has been extensively fractured, and from the cracks there have been extruded sheets of lava, and showers of volcanic ash ejected The famous hot springs of Carlsbad, and other well-known hot springs in Bohemia, are relics of these disturbances and of the volcanic phase existing in Tertiary times Occasional earthquakes show that the region is yet somewhat unstable Similar fractures in the central plateau of France allowed of the formation of Tertiary volcanoes The Puys of Auvergne are obviously very recent structures, whose activity seems to have continued almost or quite to the human period Numerous hot springs again remind us that there is

heated material probably at no great depth, and that the fracture-lines offer facilities for the heated waters to reach the surface The hot springs of the Vosges, Black Forest, Taunus, Hunsruck, Eifel, and Ardennes are probably of similar origin Many crust-blocks, in different parts of the world, have been subjected to similar geological accidents, to which much of their variety of surface is due

Plateaux of Denudation—Some plateaux are due to long-continued denudation acting on old block-mountains or on very old Alpine mountains The "felds" of Scandinavia are irregular plateaux produced by the denudation of the old Caledonian Range already described Farther east, in Finland, denudation has reduced the system to the condition of a comparative lowland, over which are scattered innumerable lakes In the Highlands of Scotland the same old mountain-system has been worn down to the condition of a plateau, dissected by the deep, irregular glens so characteristic of such a highland region The British part of the Caledonian mountain-system is thus intermediate in character and in elevation between the Kiolen and Dovrefeld of Scandinavia and the Archæan lowland of Finland This is another illustration of the difficulty of obtaining a rigid classification of land-forms

The Laurentian Highlands, north of the St Lawrence, and the greater part of Labrador, consist of very ancient rocks which have been worn down approximately to the condition of a peneplane [1]

Plateaux in Dry Regions—In regions of very low rainfall plateaux remain, on the whole, fairly level, because hollows produced either by earth-movements or by previous denudation are rapidly filled with wind-borne material The rare rains which occur are usually tor-

[1] Latin *paene*, almost

rential, and loose material from the exposed rock-surfaces is swept into the hollows. The vast plateaux of such dry regions have, therefore, undulating surfaces quite unlike the dissected plateaux of regions of moderate or heavy regular rainfall. The Arabian plateau and the Western Highlands of Scotland may be contrasted as extreme types in this respect.

Shield Lands.—Shield lands are distinctive segments of the earth's crust, which are roughly oval or circular in shape, and consist largely of very ancient rocks (usually pre-Cambrian) highly metamorphosed by the very long-continued stresses and pressures to which they have been subjected. They have maintained their individuality since at least early Palæozoic times, though in subsequent geological eras igneous intrusions may have been thrust into them and shallow-water sediments deposited upon them here and there. They contain no folded strata of Upper Palæozoic, Mesozoic, or Tertiary Age—a characteristic which teaches us that they are resistant ancient blocks that have been able to withstand the tangential pressures or thrusts by which the less resistant rocks have been thrown into folds. These shield lands are named " ancient coigns " by some writers.

Three of the best known and most fully studied shield lands are the following: (1) The Canadian Shield or Laurentian Shield, which underlies Labrador, most of Quebec and Ontario, Hudson Bay, and the plains as far west as the line of the great north-western lakes. (2) The Baltic Shield or Scandinavian Shield, which includes Finland, the Northern Baltic, and a large part of the Scandinavian Peninsula. (3) The Angara Shield, which underlies a vast area in North-Central Siberia. It is possible that the so-called Russian Platform, which seems to extend almost from the eastern Carpathians to

the Urals, is such a shield land, which is, for the time being, almost entirely covered by quite recent and comparatively recent sediments of many kinds

As a concrete example of these shield lands there follows a brief description of the Canadian Shield, known also as the Laurentian Shield or Acadian Shield Its foundation consists of plutonic, volcanic, and sedimentary rocks of pre-Cambrian Age and of considerable variety In periods long after their formation, but still in the pre-Cambrian era, these rocks were thrust into mountain arcs, and were folded, very much crushed, and intensely metamorphosed In later pre-Cambrian times, and before the dawn of the Lower Palæozoic era, these primeval mountain lands were peneplaned and reduced to nearly their present level, and to something approaching their present condition It is believed by Canadian geologists that the time occupied by the pre-Cambrian sedimentation, with its accompanying vulcanicity, the subsequent epoch of mountain-building, and the still later vast eras of denudation and peneplanation, must have been greater than all the geologic time from the beginning of the Cambrian to the present day During all those long eras, through Palæozoic, Mesozoic, and Tertiary times, the Canadian block or coign has maintained itself as a continental mass, the nucleus round which, and upon which, the North American Continent has grown, all the while offering a stout resistance to lateral thrusts, and being so hard and resistant as to suffer erosion but slowly

An interesting but comparatively slight geological accident in the long history of the Canadian Shield has given to it, at the present day, peculiar human significance As a result of the recent Ice Age the peneplaned surface of the shield land has been strewn with boulder clay and other glacial deposits, and thus a new but

temporary topography has been superimposed The drainage of the region is now characterised by innumerable lakes, large and small, from which the present rivers spill over from one lake to another, through accidental channels, forming those hundreds of waterfalls which are such a valuable asset to the country, as they become harnessed for the production of hydro-electric power

Many block-mountains, crust-block plateaux, and plateaux of denudation have not been mentioned The aim has been to show, by means of well-known examples, the nature and origin of some of the land-forms, and especially to emphasise the close relationship between the various types mentioned

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A NOTE ON AN EARTHQUAKE IN INDIA

Sir S Burrard has shown that in an earthquake in Northern India 5000 sq miles of country were upraised 5 inches

CHAPTER V

LAND-FORMS MOUNTAINS OF EROSION

ALL the land-forms discussed in the preceding chapters are attacked by the agents of erosion and denudation In various ways and in different degrees Alpine mountains, block-mountains, plateaux, volcanic accumulations are all attacked by wind, rain, frost, rivers, glaciers, and the sea The mechanical and chemical action of the atmosphere, the solvent and chemical power of water, the expansive force exerted by water in freezing, the mechanical action of water as rain or rivers, the action of ice and water in glaciers, the force of gravity, the heat of the sun—these act and interact in an infinite variety of combinations The rocks of which the land-forms are made are frittered away The word *erosion*[1] expresses very well these destructive processes The removal of the material disintegrated or set free by erosion and the uncovering or exposure of the rocks below is usually described as *denudation*[1] These two complementary processes profoundly modify the land-forms, and produce in them a series of new features The study of the forces and agents of erosion and denudation belongs to Physical Geography and Geology, we shall, as in the preceding chapters, confine

[1] Latin *erodere*, to gnaw or eat away, *-e*, out, *rodo*, I gnaw, *denudare*, to strip bare, *de*, away, *nudus*, naked

ourselves to these results which are considered to be of considerable geographical significance, always bearing in mind the conception of Geography, which is the main thesis of this book

The amount and manner of erosion and denudation and the rate at which the dissection of the land-forms takes place, will clearly depend upon the following factors

(*a*) The nature of the rocks, their resisting power, depending upon the nature of the individual rock-particles or minerals, and the cementing material in the case of certain fragmentary rocks their permeability or impermeability to water, and whether much jointed or not,

(*b*) the position and relationships of the rocks in the field, including in this the dip of the sedimentary rocks, the alignment and mode of occurrence of the igneous rocks, whether the rocks are faulted or not, and, if folded, whether slightly or intensely,

(*c*) the intensity of the forces and agents of erosion and denudation, including in this the climatic conditions, such as amount of rainfall, prevalence of much frost, and considerable variations in temperature, and the time during which the original land-forms have been subject to the attack of these forces

It will be seen in the sequel that what are usually described as residual mountains, mountains of erosion, or mountains of denudation are stages in a great cycle of processes, and, indeed, these mountains are usually a late stage The "cycle of erosion" here referred to begins with a newly upheaved land-surface, and continues until erosion and denudation have worn it down to a plain again It will be convenient to discuss in this chapter some early stages in cycles of erosion

though the land-forms produced are not mountains at all in the ordinary sense They are, however, just as important to the geographer, and their study may well be included in this place We shall study a series of concrete examples which illustrate general principles

The Dissection of the Loess of China—The *loess* of the north-west and west of China is a fine-grained yellowish loam,[1] sometimes nearly 3000 feet in thickness, it covers an area of over 200,000 square miles in the basin of the Hoang-ho or Yellow River This immense deposit chiefly consists of very fine grains of quartz and calcium carbonate, and seldom appears to be appreciably stratified Similar deposits occur in other mid-continental regions, but the finest example is in the steppe region on the north-eastern side of the immense plateau-deserts of mid-Asia Most geologists, therefore, follow Richthofen in believing that the deposit is wind-borne, and that the extremely small grains of which it consists have been carried from the high-pressure region of the great continent by the steady winter monsoon winds, the process having possibly continued since the establishment of the present general conditions about the beginning of Pleistocene time

This soft, homogeneous deposit has been dissected in a remarkable manner The plateau, which it forms, has been cut up by the rivers into blocks, which are separated by a labyrinth of deep valleys with perpendicular or overhanging walls As the loess, owing probably to slight variations in the nature of the deposit, tends to be cut back almost horizontally on certain horizons, the result is, in places, the formation of a remarkable series of terraces on the flanks of the otherwise perpendicular gorges The vertical walls of the deep valleys above

[1] Loam, cf German, *lehm*, a calcareous, sandy clay

these terraces have provided ideal conditions for the cutting of vast numbers of the cliff dwellings for which these regions have long been famous

The "Bad Lands" of Dakota—In South Dakota, and adjoining parts of Wyoming, there is a wide region occupied by soft horizontal strata, chiefly clays and soft sandstones of Mesozoic Age The rainfall is not more than fifteen inches per annum, and occurs largely in storms The summer is very hot, and the smaller streams are then dried up The soft, horizontal strata have been dissected by numerous steep-sided channels, enclosing " mesas " or blocks of land which are accessible from each other only with some difficulty The region thus merits the name " *mauvaises terres pour traverser* " given to it by the early French explorers Hot and waterless at times, with irritating alkaline dust blowing, the cliffs and plateau-surfaces almost destitute of vegetation, these deeply dissected lands are of profound interest to the student of Physical Geography, and also to the palæontologist who finds in the soft strata some of the most perfect and wonderful remains of extinct animals yet known

The Cañons of Colorado—Probably the most magnificent examples of deep gorges cut in approximately horizontal rocks are the stupendous cañons west of the Rocky Mountains A vast succession of strata of age varying from Palæozoic to late Mesozoic, capped in places by immense lava-flows, has been dissected by the Colorado and other rivers The region is a dry one, and there is little of the subaerial weathering which goes on in humid localities The rivers are fed from the snows of the Rocky Mountains, and flow through the almost rainless plateaux, cutting deep gorges, the sides of which do not recede at the rate they would if the atmosphere contained much moisture, and if the

ordinary erosion of rain and frost took place This vast plateau area of almost horizontal strata stands many thousands of feet above the base level of erosion, and so the gorges reach an enormous depth, in places as much as 6000 feet Immense dissected blocks of the sedimentary and volcanic rocks are the result, these have also been termed *mesas* by the early Spanish explorers and settlers

Cañon-like Gorges in other Regions—Gorges of somewhat similar type are found in many parts of the world, but nowhere on so grand a scale A remarkable dissected country is that of Southern Abyssinia The rocks there are chiefly volcanic—trachytes, basalts, and tuffs, and lie almost horizontally The volcanic plateau rising to 7000 feet or more above sea-level, has been dissected into a remarkable system of blocks similar to the mesas already mentioned The rocks, owing to differences in texture at different levels, and to their general horizontal alignment, show magnificent terraces, with mighty walls of 3000 feet rising sheer from them Some of the cañon-like gorges reach 5000 feet in depth The summits of the dissected blocks—called "Ambas" in that country—and the less easily accessible terraces, are often crowned by fortresses, or are the seat of monasteries

We may also instance here the rocks of the Nieuweld plateau in South-East Africa which culminates in the deeply dissected Drakensberg The rocks are shales, grits, and sandstones, covered by more-resistant igneous rocks The Drakensberg high plateau has been cut into a series of tabular mountain-blocks, sometimes having the appearance of gigantic fortresses Giant's Castle, 9000 feet above sea-level, is a well-known example In the neighbourhood of Mont Aux Sources, on the north-west border of Natal, the magnificent gorges of

the upper Tugela River are quite cañon-like in character The gorge known as "The Great Cañon" is five miles in length below the famous Tugela Falls, and in places is not more than 40 feet wide There are many cliffs which rise almost vertically for thousands of feet, in the middle of one such series the main falls of the Tugela plunge over 2000 feet in three steps In the Champagne Castle region a little to the south of Mont Aux Sources the Little Drakensberg is separated from the main range by a gorge 7000 feet deep Throughout the whole of the Drakensberg, but especially in the three regions mentioned, the dissection of the plateau has left magnificent examples of isolated mountains of erosion or denudation, these stand out from the serrated edge of the plateau as giant outliers, separated from each other by the smaller tributaries of the Tugela and other rivers

We may now turn to similar gorges and dissected blocks, cut out of limestone plateaux The fine gorges of the Tarn in South-central France may be especially mentioned The rainfall is there considerable, but the well-jointed limestone allows the rain-water to pass through to form underground streams, and the direct downward cutting of the main stream therefore proceeds more rapidly than the erosion of the side walls In this way deep gorges are cut in the limestone rock The smaller gorges of the carboniferous limestone regions of Britain, notably those of the West Riding of Yorkshire, Derbyshire, and the Mendips, are similar to those of the Tarn The jointed limestone allows of the production of gorges with more or less vertical walls

Saxon Switzerland and the Swabian Jura—In the region known as Saxon Switzerland, on the borderland of Bohemia and Saxony, there are well-bedded Cretaceous

grits which have been dissected into plateau-like blocks by systems of vertical fissures. One of the best examples is the gorge by which the Elbe passes through from Bohemia to Saxony, and which has been described as a good example of a cañon. In the Jurassic region of Swabia the Danube and its northern tributaries, and the feeders of the Neckar, have cut deep gorges, in the bottom of some of which rivers still flow, while many are "dry valleys." In the northern part of this dissected land there are prominent rock-masses with precipitous faces, standing out from the gently sloping tableland as islands or peninsulas.

In regions where there is a moderate or heavy rainfall, and where consequently frost and rain may erode the sides of the river-valleys, the cañon character becomes modified. The valley becomes relatively wider, and the intermediate blocks of land lose something of their plateau character. These effects are best illustrated and studied in regions where the strata are horizontal or only gently inclined, and where sandstones and grits form a considerable portion of the rocks.

The Plateaux of the North Pennines.—There are two distinct Pennine regions. The moorlands north of the Craven Gap have a structure somewhat different from that of the Southern Pennines. The Northern Pennines consist of a series of crust-blocks, bounded to the west by prominent faults. The four chief fault-systems are the Tyne, the Pennine, the Dent, and the Craven, two of which, the Pennine and the Craven, form distinct features in the Northern Pennines. The positions and relations of the various structural divisions will be better understood by reference to a simplified geological map in which the great faults are shown somewhat diagrammatically (*see* Fig. 10).

There are, it will be seen, three great blocks of Car-

FIG 10 —A SIMPLIFIED GEOLOGICAL MAP OF THE NORTH OF ENGLAND, TO ILLUSTRATE THE GEOGRAPHICAL DIVISIONS

1 = Granite masses 2 = Lower Palæozoic Rocks 3*a* = Carboniferous Limestone 3*b* = Millstone Grit 3*c* = Coal Measures 4 = New Red Sandstone (Permian, Trias) 5 = Jurassic Rocks 6 = Cretaceous Rocks (Chalk, etc) 7 = Recent deposits

Note the great Fault Systems of the Northern Pennines The Faults, reading in order from north to south, are Tyne Fault, Pennine Fault, Dent Fault, Craven Fault Each of these faults is more or less complex or compound in structure

The chief, clearly defined Geographical divisions, as determined by the rocks, rock structure, and rock position, are The Northern Pennines, chiefly Carboniferous Limestone, with denudation relics of Millstone Grit, the Southern Pennines, chiefly Millstone Grit, with the two great coal field systems on the flanks, the Lake District system of Older Palæozoic Rocks, with masses of Granite, and with a rim of Carboniferous Rocks, the Bowland Fells, between the Craven Fault and the North Lancashire Plain, Millstone Grit and Carboniferous Limestone, with the little Ingleton coal-field at the north eastern corner, the large coal fields determining the great industrial areas of the north, the New Red Sandstone plains, Lancashire and Cheshire, North-Eastern, and Vale of Eden, the North York Moors, Jurassic Rocks, the Yorkshire Wolds, Chalk rock, the Lincolnshire Scarps and Wolds and the part of the Fenlands shown on the map

boniferous strata, in which the dominant formation is the Carboniferous Limestone, with irregular cappings of Millstone Grit These may be called the Cross Fell, the Dent, and the Penygent blocks Each of these, but more particularly the last-named, illustrates very clearly the dissection of a plateau and the production of well-defined residual mountains An east and west section—somewhat diagrammatic—through the Craven Fault, Ingleborough, Penygent, and Great Whernside illustrates the whole structure remarkably well, and

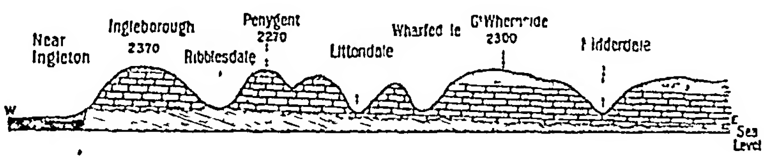

FIG 11 —DIAGRAMMATIC HORIZONTAL SECTION ACROSS THE CRAVEN FAULT AND THE PENNINE MOORS TO THE EAST

On the east of the fault Millstone Grit overlies Carboniferous Limestone, and the latter lies unconformably on Lower Palæozoic Rocks, which come to the surface in Ribblesdale On the west of the fault, near Ingleton, Permian Rocks (New Red Sandstone) overlie Coal Measures The strata are shown diagrammatically, with the vertical scale exaggerated

shows the relics of the Millstone Grit as the caps of the three conspicuous mountains named, and rising from the platform of the Carboniferous Limestone into which the rivers Ribble and Wharfe have cut their valleys In Ribblesdale, the river in its cutting-down has reached the Older Palæozoic rocks below the floor of the Carboniferous Limestone

In the case last considered the residual mountains constitute only a fraction of the original tableland of Carboniferous rocks out of which they have been carved The lower strata of the Carboniferous Limestone are now in a comparatively early stage of dissection, but

[*Photo T. E. Capstick, Ingleton*

PLATE IX.—INGLEBOROUGH SEEN FROM THE WEST

A *Residual Mountain* of *Yoredale Rocks* and *Millstone Grit*, rising from a broad platform of *Carboniferous Limestone*

The summit of the mountain consists of Millstone Grit; under this are shales, and below this the Main Limestone (the highest massive limestone in the Yoredale Series); this forms the sharp shoulder so well seen in the picture. Below this come shales, limestones, and sandstones, and under these the *Great Scar Limestone*. The latter limestone is from 600 to 900 feet in thickness, and forms the great plateau or raised platform of Ribblehead and Chapel le Dale, from which rise Ingleborough, Whernside, and Penygent, the three residual mountains which are so similar in structure.

N.B.—Whernside, near Ribblehead, should not be confused with Great Whernside, between Wharfedale and Nidderdale.

[*Photo by Geological Survey*

Plate X.—A Mountain of Horizontal Torridon Sandstone (A) enclosing a Mountain of Lewisian Gneiss (B)

of the upper beds of the same formation very considerable portions have been removed, the Millstone Grit caps of the mountain-masses are only a very small remainder of the once vast extent of that formation Quite possibly there have once been newer strata overlying the whole of those at present exposed,—Coal Measures, Permian and Mesozoic rocks,—but, if so, they have been completely removed by denudation It is clear, therefore, that erosion and denudation have proceeded to a comparatively advanced stage We may now consider cases where the process has reached a more advanced stage

The Torridonian Mountains of Scotland —In the extreme north-west of Scotland there are many bold mountains which consist of almost horizontal grits and quartzites of the Torridonian series These rocks are pre-Cambrian sediments, and are thus of very great geological antiquity They overlie unconformably the Archæan schists and gneisses of the North-Western Highlands The pre-Cambrian sediments have clearly once extended over a wide area, but only the merest relics are now left Through long geological ages erosion and denudation have continued, and nearly the whole of the once widespread strata, 7000 to 8000 feet in thickness, has been removed A number of isolated mountains may be seen in Sutherland and Ross-shire, the lower parts of which are composed of almost horizontal Torridon Sandstone, capped by bold cones of quartzite, the whole resting on a much denuded platform of Archæan rocks These are true residual mountains, and the region is now in a late stage of the cycle of erosion

"Monadnocks"—Similar true residual mountains—the relics of the dissection of some kind of upland or plateau—are found in many parts of the world An

example, which has become famous, is Mount Monadnock, in New Hampshire, U S A This is an Archæan peak of about 3500 feet above sea-level, which now stands up as an isolated mass, and a prominent landmark—the result of the almost complete destruction of an old plateau The name of this residual mountain has been proposed by Prof W M Davis as a technical name by which all such remnants of dissected uplands should be known The name is not a euphonious one, but it has already won a place, if a somewhat grudging one, in geographical literature

Dissection of a Dome—The English Lake District—In the examples we have studied up to this point the strata have been, for the most part, horizontal, or only dipping at a low angle We now come to the study of the dissection of upland regions where the rocks are much folded The first illustration is the English Lake District, a region which furnishes excellent illustrations of residual mountains Such mountains as Scafell, Helvellyn, and Fairfield, for example, stand out comparatively isolated, but they are clearly relics of a once continuous mass The Lake District consists essentially of a central region of folded and faulted Older Palæozoic rocks, partly surrounded by a girdle of Carboniferous rocks, with another incomplete outer girdle of New Red Sandstone rocks The central mass has been uplifted into a sort of elliptical dome, somewhat like a shallow spoon, convex side upwards The axis of the upfold runs from east to west, and the drainage thus shows a sort of radial arrangement with more emphasis on north and south than on east and west directions Dr Marr has shown that the uplift of this dome probably took place in Miocene times At that period, the older rocks were possibly covered with Jurassic and Cretaceous

rocks The drainage then set up has been inherited by the present much-folded and faulted central lake region, some of the complex folding and faulting of which belongs to a much earlier period It is on this account that the river-valleys so often cut across the grain of the rocks Aided by numerous faults, the drainage of this region of heavy rains has cut deeply into the dome and produced the striking assemblage of mountains and deeply trenched valleys It ought to be added that Dr Marr is of opinion that erosion by glaciers has played a considerable part in the gouging

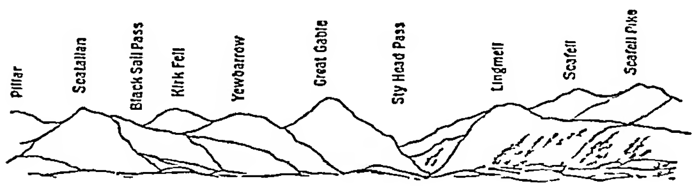

FIG 12 —A DISSECTED DOME

A sketch of the profile of some Lake District mountains as seen from near Seascale The deep valley is Wastdale, with the famous screes on the slopes above Wastwater

out of some of the valleys The general question of glacial erosion is still one of the thorny questions of geology, but Dr Marr has paid so much attention to the physical history of the Lake District that his opinion must carry considerable weight

Snowdon as a Residual Mountain —From this brief summary of the dissection of a dome we may conveniently pass to the study of Snowdon as a type of residual mountains of another character, but in many respects not unlike some of the Lake District mountains Just as Dr Marr has interpreted for us the structure and the history of the Lake District, so Prof Fearnsides has done for the mountains of North Wales

He has taught us the successive phases in the history of this interesting region In the three long periods of Older Palæozoic time — the Cambrian, Ordovician, and Silurian—the building up of the material took place There are immense thicknesses of sedimentary rocks of Cambrian, Ordovician, and Silurian Age, and, in addition, there are volcanic rocks formed in the Ordovician period These include acid and intermediate lavas—rhyolites and andesites—and thick deposits of volcanic ash, of which a good example is the well-known fossiliferous ash which forms the summit of Snowdon Most, if not all, of the volcanic rocks of the Snowdon district are of submarine origin, and both beds of volcanic ash and lavas are interbedded with ordinary sediments. These Older Palæozoic periods were, so far as North Wales is concerned, practically one long marine epoch when immense thicknesses of their rocks were laid down

The second phase in the history of Snowdonia began at the end of Silurian or in early Devonian time The formation of the folded Caledonian Alps in the Devonian continent has already been mentioned The modern Alpine ranges have their fringing-ranges or foreland mountains, such as, for example, the Jura, so the Caledonian range of Devonian times had its foreland mountains Such a "Jura range" seems to have extended along a line through Anglesey and the Southern Lake District The production of this foreland range included what is termed the *regional* folding of the rocks of Snowdonia This sub-stage was followed, probably in later Devonian time, by intense local folding, including much compression and faulting Taking these two correlated processes, regional folding and local crumpling, as one great compound phase, it may be said that in the Devonian period the larger anticlines

and synclines of the region were produced, in addition to those local changes, such as the production of slaty cleavage in the fine-grained sediments of North Wales In this immediate study it is important to realise that one broad and shallow synclinal fold included what is now Snowdon Mountain with its sedimentary and igneous rocks

The last stage in the production of the mountain system as it now exists was, of course, the dissection and partial destruction of the uplifted and folded rocks Much of the history of this stage is still obscure During the vast time which has elapsed since the dawn of the

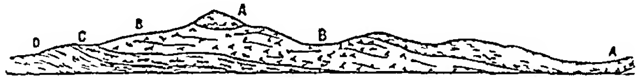

Fig 13—A Diagrammatic Section across the Rocks of Snowdon to show that it is a "Residual Mountain," resulting from the Long continued Denudation of a Series of Lower Palæozoic Rocks

A Beds of volcanic Ash, containing fossils B Acid lavas C Grit beds D Slates The whole shown quite diagrammatically

Carboniferous period, the region now under discussion has been subject to many vicissitudes Possibly the whole of North Wales was covered by the widespread upper Cretaceous sea, but this is by no means universally accepted It is sufficient to say that erosion and denudation, including the erosive work of ice in the glacial period, have removed vast quantities of material, and have cut deep into the original system Snowdon itself remains a magnificent monument of these various stages, a residual mountain carved out of folded and faulted aqueous and igneous rocks belonging to ancient geological periods A diagrammatic section of the rocks of Snowdon may render the structure and history clearer (*see* Fig 13)

A *modern* foreland range clearly offers the same kind of opportunity for the forces of erosion and denudation The Jura of the Franco-Swiss border has been already mentioned as a type of a foreland range As may be expected, it is already deeply dissected, and the traveller, by rail from Dôle, through Pontarlier to Lausanne, sees many a reminder that, in this younger range, mountains of denudation are being formed The Jura range is in a much less advanced stage than the much worn Snowdon range

We may include here a brief description of *Escarpments*, with some account of their further dissection Escarpments are often produced by the denudation of stratified rocks which form one limb or slope of either a simple anticline or a syncline Some of the most famous examples have been produced in folds of a broad and shallow character, and similar results may follow where horizontal strata, over a wide stretch of country, have received a distinct tilt in one definite direction An escarpment may be defined as the boundary ridge or inland cliff of a formation, following the line of strike of the strata It is clear that escarpments may exist in horizontal strata, but the more striking cases occur in formations where the beds have a low dip, in these cases there is a " scarp " edge or cliff facing in one direction and a gently inclined dip-slope in the direction at right-angles to the line of the escarpment The reader may refer again to Figs 5 and 6, showing the Jurassic limestone and chalk escarpments of middle England and the chalk escarpments of the North and South Downs

The series of escarpments in eastern France is worth more than a passing mention, as the whole system illustrates remarkably well the denudation of a region consisting of alternations of hard and soft stratified rocks succeeding each other regularly, and having a low

dip The traveller from the Zabern Gate (north of the Vosges) to Paris passes over three well-defined escarpments, separated by belts of lowland formed of less-resistant strata

(1) The Jurassic escarpment of the upper Meuse region and the Plateau de Langres

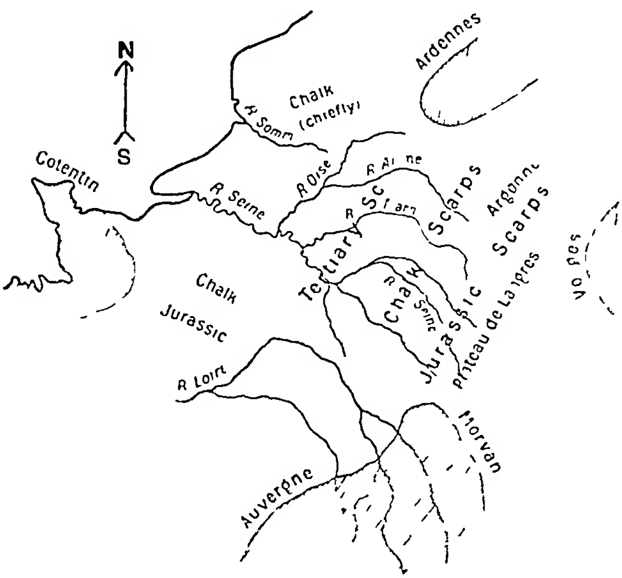

FIG 14—A DIAGRAM MAP OF THE PARIS BASIN TO SHOW ITS STRUCTURE

The wider "basin" is surrounded by a number of blocks of much older Rocks The Tertiary (inner) "basin" is surrounded by Mesozoic Rocks (*See* the section, Fig 15)

(2) The chalk escarpment of the Argonne and the Champagne

(3) The Tertiary escarpment of the Soissonais and the Laonnais nearer to Paris

The rivers converging on Paris flow across these terrains as dip-slope streams Beginning on the high ground of the Plateau de Langres they flow down its gentle slopes towards the north until the sharp cliffs of the chalk Argonne are reached The rivers cut through this in defiles which have been famous in all the wars which have had Paris as their objective After passing the chalk region, the converging rivers cut through the Tertiary limestones by such gaps as the famous one at Soissons Thus the whole country has been dissected

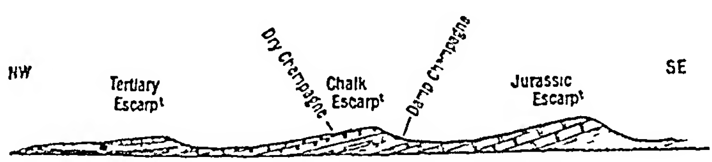

FIG 15 —A DIAGRAMMATIC SECTION FROM N W TO S E, FROM THE PARIS BASIN TO THE REGION BEYOND THE JURASSIC LIMESTONE PLATEAU, AND THROUGH THE SERIES OF FAMOUS ESCARPMENTS

into a series of blocks having on the whole, a gentle tilt towards the north-west Paris is the natural focus of these lands

The English North Downs are cut through by the Wey, Mole, and Medway, the Thames has cut through the chalk at Goring and Maidenhead, thus separating the Chilterns from the Berkshire Downs, and there are numerous old valleys through the Chilterns, dry valleys or "wind-gaps," through which the railway routes from the plains beyond the escarpments converge on London

The plateau of the Swabian Jura, already referred to in this chapter, is a very gently sloping dip-slope, which has its escarpment or inland cliff edge facing Stuttgart, and the valley of the Neckar to the north-west The dip-slope is towards Ulm and the upper Danube Valley

The Dissection of Alpine Mountain Ranges.—From the study of the dissection of Alpine forelands and some escarpments of Alpine origin we may pass naturally to the dissection of Alpine mountains themselves The structure and origin of these complex mountain systems have been discussed in Chapter IV It only remains, in this chapter, to emphasise that most of the prominent mountain "peaks" of an Alpine system are true residual mountains To repeat what was said in the earlier chapter, the forces of erosion are particularly active and dissection proceeds very rapidly Hence the ranges are being cut up into the sierra-like form that is characteristic of these mountain systems For example, the famous Aiguilles of the Mont Blanc group are obviously dissected pinnacles carved out of a mighty complex When the great Alpine investigator, de Saussure, first saw the residual fragments of Mesozoic strata overlying the older rocks in the middle of the range, and realised that these newer rocks had once been continuous from one side of the mighty range to the other, he caught probably the first glimpse of the important part played by erosion and denudation in the production of a sierra-like folded mountain range

The Production of a Peneplane—If we imagine the denudation of a mountain range of any type to be continued sufficiently long, it is conceivable that the rivers may finally carry away the gradually dwindling mountains of denudation until a worn-down, fairly even surface is produced, with a gradual slope towards the sea Such a final result was termed a *Peneplain* by Prof W M Davis, of Harvard, U S A Following a suggestion by Prof J W Gregory we use the modified form, *peneplane* Most of Finland has already reached that stage, another example is the surface of the Archæan land north of the St Lawrence, the Laurentian "plateau" of

some writers As already mentioned, these particular peneplanes are final stages in the wearing-down of Alpine mountain ranges It is a disputed question whether any subaerial peneplanes exist in Britain The late Mr Jukes-Browne even doubted their possibility, and considered any planes which had been produced as due to marine denudation

The Highlands of Scotland—This deeply dissected region consists of a plateau or an old peneplane cut up by a network of river-glens There is nothing even remotely resembling a mountain chain The abundant rain of this western edge of the continent has long supplied water for the countless rapid streams These torrents flow through the deep and narrow glens, which may have been largely initiated by faulting, but which have been afterwards cut down by frost and rivers, and largely modified by ice-action during the glacial period The immense folds and faults of the once great Alpine system are but faintly reflected in the present topography of this interesting region

From the study of these various examples it is seen how Alpine-mountains, block-mountains, plateaux, mountains of accumulation, and the various sub-types of residual mountains are all intimately connected, and that the study of one form is bound up with that of others For purposes of description we find it convenient to use the different names, and it is necessary, in our investigations, to consider somewhat extreme examples When we apply the knowledge gained from the study of extreme types to the general study of the earth's surface, we are at once struck with the frequency with which mixed or transition types occur To attempt to classify rigidly, and to place the different mountain-forms in sharply defined classes is contrary to the true spirit of science

We will conclude this chapter by quoting a translation of the final paragraph from the late Prof A de Lapparent's *Leçons de Géographie Physique*, a work to which all students of Geography stand indebted " We shall not carry further our rapid review of different types of mountains , stating yet again that our object was not to establish a systematic classification, but rather to show how great was the variety of mountain types, and to indicate, whenever it was possible, the precise relations which must always exist between the geographical aspect and the geological conditions "

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CHAPTER VI

LAND-FORMS PLAINS

PLAINS are areas with a fairly even surface and not very far above sea-level A large and even surface raised considerably above sea-level and above the surrounding land is better treated as a plateau, though it is not always easy to decide whether a given region should be classed as a plain or plateau Professor J W Gregory divides plains into four groups, two of denudation and two of deposition

1 Peneplanes have been produced by the planing down of a country by subaerial erosion and river denudation They have already been mentioned in the preceding chapter

2 Plains of marine denudation have been formed by the planing action of the surf attacking the coasts By the cutting away of the cliffs during storms and at high tides, and the planing down of the belt of land between high and low tides into an even surface, the plain of marine denudation gradually extends back into the land

3 Alluvial plains or plains of river deposit The material is brought down from the higher parts of the river and is deposited when the water of the river begins to flow more slowly The river gradually raises its bed, then breaks through its banks, and by continually changing its direction gradually makes a plain of deposited material

4 Coastal plains of deposition which occur on some of the continental margins They are formed by the deposition of material in shallow water, and are submarine plains of deposit, which have been raised by subsequent uplift above the sea-level

So many plains combine the characteristics of at least two of the above that we shall study them geographically rather than in genetic groups, at the same time making some mention of what is known concerning their mode of formation The emphasis may, however, in this book, rightly be on the geographical rather than on the genetic point of view

It is obvious that plains will not usually reveal so much of their underlying structure and origin as do other land-forms The surface, and a very little depth below, is all that is exposed in many cases, except in river cuttings and in cliffs where the sea has cut into the rocks of the plain We owe to occasional borings for water, salt, petroleum, and coal, much of our knowledge of the underlying rocks

We shall discuss, in the first place, some of the greater plains of the world

Plains of Eurasia — The Great European Plain.— In this is included the great plain stretching across Europe from the low chalk " hills " and chalk cliffs of north-eastern France and the chalk hills of eastern England to the Arctic Ocean, the Urals, and the Caucasus, and including those submerged parts, the North Sea, most of the Baltic, and the White Sea This plain is obviously of great importance in European geography and is worth somewhat extended study From it we may readily illustrate some important general principles Its western part, from the south-western corner of the North Sea to the river Niemen, is mainly covered with Pleistocene deposits—river allu-

vium, blown sands, glacial deposits, and peat The wider eastern part, in Russia, is somewhat different, and consists of Cainozoic, Mesozoic, and Palæozoic rocks more or less covered by glacial beds, modified loess, or steppe sands and dust The great plain is thus divided into western and eastern parts the western we may call the Netherlands-Germanic plain, the eastern part is the Russian plain These greater divisions are capable of subdivision into lesser regions, each with its peculiar characteristics

Flanders.—The famous plain of Flanders extends from near Cape Gris Nez to the mouth of the Scheldt The surface is sea-mud and sand and river alluvium, under which are clays and sands of Tertiary age If the soil and subsoil are clayey, the land is extremely fertile, as, for example, the rich lands round Ypres, but if it is sandy it is not nearly so fertile, as may be seen in the comparatively barren land between Ghent and Bruges The part of the plain between Bruges and Antwerp is a region with sand at the surface, but underneath is Tertiary clay, which keeps the land moist Long-continued deep ploughing has brought up much of this clay subsoil and mixed it with the sand, making this region of Wass or Waes one of the fertile parts of Flanders Along the coast from Dunkirk to the mouth of the Scheldt are sand dunes, where the contest between the sea and the land is still going on Behind the sand dunes are lagoons, the "wadden" of the Flemish

The Netherlands—Eastward of the Scheldt estuary is a somewhat new type, the low country *par excellence*, it is chiefly the delta of the Rhine and Meuse Here still continues the battle between rivers, winds, and sea, but to explain the present conformation we have also to call in the work of ice in the Pleistocene glacial epoch Along the almost straight coast of North

Western Holland are sand dunes, which, near Haarlem, are three miles in width These are the work of the wind, which drives them farther and farther inland, leaving the now unprotected coast to the ravages of the waves, but their landward progress has now been somewhat arrested by the planting of "bent-grass," the long roots of which bind the sand Inside the dunes is the variable belt of wadden and farther inland the great area which was once marsh land This lowland country reaches 25 miles in width, and extends along the banks of the distributaries of the Rhine The Rhine mud has been deposited here through long ages, the rivers have raised their beds, and man has been compelled to confine them in well-defined channels by a magnificent system of dykes The marshy meadows of this country have their surplus water pumped out, formerly chiefly by windmills [1] Beyond the low marsh country, and farther inland, there is a quite different belt, the Campine of Belgium and the Geest of Holland This is dry, sandy, infertile, and very thinly peopled It is mainly covered with brown heath through which little mounds of sand protrude It is over 300 feet in height in the east of the Veluwe or Bad Island of Holland This interruption in the flat land is due to the melting ice of the great ice age The borders of the Scandinavian ice reached this region, and the waters of the melting ice spread out here grit and pebbles from Scandinavia The Rhine drainage was also bringing down its alluvium and throwing it against this northern drift Thus was formed the mixture of enormous masses of stones, mud, and sand, found in the mounds of this infertile Campine and Geest

The sea broke through the eastern cordon of dunes in the thirteenth century, and converted the old Lake

[1] Windmills have been largely replaced by oil driven pumping machinery

Flavo into the immense Zuyder Zee, thus extending a re-conquest which the sea had been making for some time. Before the beginning of the glacial period the Rhine seems to have flowed northward over an old land and emptied itself somewhere between the Dogger Bank and Denmark. Since that time, and after the disappearance of the North Sea ice-sheet, the sea, aided by a general sinking of the land, has recovered much of its lost territory.

The plains of Flanders and the Netherlands are thus the work of winds, rivers, glaciers, and the sea, combined with sinking of the land since the glacial period.

From the Zuyder Zee to the Mouth of the Elbe.—The types found in the Netherlands are, on the whole, continued to the Elbe region—dunes, wadden, marsh land, and heath; excepting that not much of the marsh land is below sea-level, and dykes are consequently not so numerous. The Campine type of country does not rise to so great an altitude as in the Veluwe of Holland; it is here a flat, barren land. The alluvium of the Ems and the Weser is spread over the lowlands. The line of dunes is on the Frisian Islands—long, low islands having their axes parallel to the coast; and the wadden are represented by the narrow belt of sea between the islands and the mainland. There are immense areas of peaty marshes inland, that of Oldenburg being perhaps the best known. The attacks of the sea, which formed the Zuyder Zee in the thirteenth century, also commenced the formation of the Dollart See and Jade Bay, and broke through the dunes forming the long line of islands.[1]

From the Mouth of the Elbe to the Memel.—The coasts are now more cliff-like, and there is nothing quite like the wadden of the western parts of the great plain. The glacial deposits corresponding to the Campine and Geest now increase in importance

[1] See p. 127.

because of increasing thickness The most westerly and most important of these larger glacial moraines is the Luneberg Heath, on the south-west side of the Elbe, at the very beginning of this modified country, where sands are mixed with immense erratics, many of which are of Scandinavian origin This is the least fertile part of Germany, a land with a few scattered woods, and given over to the grazing of sheep

Farther east is a distinctly morainic land, with numerous glacial lakes, the whole lying nearly parallel to the Baltic coast until the frontier of Russia is reached The Masurian Lakes in East Prussia are the most easterly part of this region Throughout the whole of this part of the plain the morainic "hills" are comparatively infertile, while the "valleys" are covered with river alluvium, and are the granary of this Prussian plain

On the coast of the Baltic there has been some sinking of the land, and, on the other hand, the latter has been gaining on the sea by means of deposition As an example of the sinking, the Isle of Rugen is known to have been once part of the mainland The Frisches Haff, near Dantzig, was formed in 1510 by an inrush of the sea, probably due to sinking of the land In all probability the great Kurisches Haff was formed in the same way The long spits of land, the *nehrungs*, are like sand dunes in their origin, and are formed by the westerly winds blowing the sand into long extended dunes

From the cliffs of Calais to the eastern end of the Masurian Lakes almost the whole plain is covered with Pleistocene deposits, except where, in a very few localities, strata older than the Pleistocene are seen at the surface, these usually having been exposed by the rivers cutting through the newer strata and thus revealing the older beds Very little is known of the strata below the Pleistocene beds Borings have

revealed Tertiary strata here and Mesozoic strata there, containing deposits of common salt and gypsum, while, in the Campine of Belgium, coal-beds have been reached

The Russian Plain and its Divisions —Almost the whole of European Russia is a great plain[1] From the Arctic Sea to the Black Sea, from Finland to the Caucasus, and from the Baltic to the Urals, the country is one vast expanse of relatively flat land The so-called Valdai Hills rise to only 1100 feet above sea-level, they are the highest part of the very slightly elevated plain, a very trifling swelling in an almost illimitable stretch of flat country In other respects the land is quite unique

The geological map shows Mesozoic and Palæozoic rocks with a comparatively small area of marine and lacustrine Tertiary and Pleistocene strata in the south-east, with glacial deposits over a large part of Northern Russia

Under the modern deposits is the Russian Platform of ancient rocks, one of the most stable parts of the earth's crust Some parts are covered by sediments as old as the Silurian period, which are here horizontal, having been very little disturbed throughout the long periods which have seen folds and crust-block disturbances in other parts of the world Long-continued erosion has planed down the land, and there have been few invasions of the sea over this vast territory This, therefore, may be regarded as a great plain, levelled by erosion and denudation acting through very long geological ages

There are three distinct sub-regions in the great plain outside Finland and the lake region generally, which has been mentioned already These are the Tundra, near the Arctic Sea, with the usual typical

[1] Which also includes Estonia, Latvia, Lithuania, and Eastern Poland

character of these marshy, icebound plains, next an immense zone covered by Pleistocene glacial deposits, now a land of marshes and of forests, and finally, the great grass region of the south and south-east, beyond the limits of former ice action, this extends to the Black Sea and the Caspian These owe their different characteristics chiefly to differences in climate and, in a lesser degree, to differences in the nature of their superficial deposits

The Tundra—These icy plains extend from Archangel eastward over the low Timan range to the slopes of the Urals and southward to the zone of coniferous forests The cold of winter is intense, and the atmosphere is very dry Precipitation—chiefly snowfall—is consequently slight The vegetation consists of lichens and mosses and a few heath plants, forest trees being absent, except in a few of the more favoured regions The ground is perpetually frozen to a considerable depth, and the rivers are ice-bound for more than half the year The frozen deltas compel the rivers to overflow in the early summer, and then their alluvium is spread over the country to be frozen in with the general mass in the next winter The Tundra plains are alluvial plains, with a surface largely covered with "icy marshes," the whole, in the case of Russia, apparently resting on a platform of Palæozoic and Mesozoic rocks

The Middle Plain of Russia—This is distinguished from the other elements of the Russian plain by the frequent presence of erratics and other glacial deposits, thus making it in some respects like the plain of North Germany Glacial deposits reach a thickness of 650 feet in Poland The topography is remarkably uniform, the rivers form marshy extensions, and the slopes of the slightly higher ground are covered with immense forests, coniferous in the northern part, and

deciduous trees in the southern part The remarkable character of the drainage is seen from the fact that the average fall of the Volga is 1 in 10,000, one of its tributaries receives some of its water from within 100 miles of Lake Ladoga The famous marshes of the Pripet are to some extent the counterpart of the marshy region of Masuria in East Prussia This once glaciated plain has a substratum of Palæozoic and Mesozoic rocks, which are brought to light in the deeper cuttings of the rivers It is a second part of the plain of the Russian platform

The Prairie-Steppe Region of the South and East—This region outside the glaciated zone is divisible into two sub-regions, depending mainly upon climatic differences, these are the country of the Tchernozoum or the Black Earth region, and the steppe land of the south and south-east The surface deposits of the Black Earth zone are loess-like loam, probably formed in part like the loess of China, and partly by sands and muds brought by the rivers from the glaciated region This mixture of sands and clays formed a suitable terrain in which herbaceous plants grew rapidly, and the intermingling of the decayed vegetation with the alluvial, glacial, and æolian deposits has produced the fertile soil of this well-known region

The Black Earth zone extends from the south-western parts of the Russian platform, from what Dr Mill calls "Carpathia" to the Urals, the northern boundary being roughly from about lat 54° in the south-west to lat 57° in the north-east The southern boundary is not so well defined, but dovetails into the steppe The whole area is at least two and a half times the size of Great Britain It is distinguished by the remarkable fertility of its soil, lucerne, wheat, beetroot, and, in the extreme south, maize doing remarkably

well. The grass prairies and steppes are south and south-east of the Black Earth region. The rainfall diminishes towards the south-east until in the lowlands adjoining the Caspian there is a fall of about six inches a year, compared with sixteen inches at Odessa, and twenty-one inches at Kiev.

But the difference between the Black Earth region and the steppe is not simply one of present differences of rainfall. In recent geological times a sea occupied the region east of the Don; the soil, therefore, is too salty for rich growth, and this, combined with the low rainfall, produces the true steppes of the Don and the lower Volga. The sea extended from the Black Sea through the Manych depression to the Caspian and northwards, where it probably had a connection with the Arctic Sea through the Ob Valley.

The great Russian plain is thus an old platform of long-continued denudation, lowered by earth-movements, and covered by glacial, river, sea, and wind-borne deposits, in places mingled with much vegetable debris, the whole now having differences in climate sufficient to divide it into well-defined regions.

The Plains of Western Siberia.—From the steeper eastern slopes of the Urals to the Yenisei there is a vast plain similar to that of European Russia. The northern part is an immense area of tundra which stretches without interruption from the estuary of the Ob to that of the Yenisei. Eight long winter months seal up the land. Then, with the coming of spring, the rivers, flowing from the south, overflow the ice-locked northern plains, and, as in Europe, only on a greater scale, river alluvium is spread over the land to be frozen in by the next long winter's frost. South of this is the great forest zone, which, north of Tobolsk, is a land of marshes and thick forests. This was not

glaciated like the middle region of European Russia, but is mainly covered with Pleistocene fresh-water deposits In the south is a black-earth region, where wind-borne sand and loam, mixed with vegetable debris, have accumulated since the Miocene period, when the arm of the great sea left it

This great West Siberian plain is one of the most level plains known For over 1000 miles in each direction there is no part more than 600 feet above sea-level The basis of this vast plain had been levelled by denudation during the long eras from the Carboniferous period to the beginning of the Tertiary The Tertiary and Pleistocene seas and lakes have filled up some of the inequalities, and the rivers have continued the levelling process, producing the apparently illimitable expanse of plain which the Trans-Siberian Railway crosses after leaving the Urals

The Aralo-Caspian Depression—This is the greatest region of its kind on the earth's surface, a good deal of it is below the level of the surface of the nearest ocean It was formerly occupied by the sea which extended westward through the Manych depression to the Black Sea and northward to the Ob basin and the Arctic The region north of the Aral Sea is now dotted over with lakes without outlet The Caspian formerly had a great extension from east to west, its north to south extension is now much the greater The Aral was once much larger than it is now, and probably extended westward along the Sarakamych depression, which is even lower than the Caspian Sea This depression is now occupied by brackish lakes The whole region is probably one of gradually diminishing rainfall, and the steppes and deserts are of comparatively modern origin The rivers which come from the great Thian-Shan, Hindu Kush, and Khorassan ranges bring down

immense quantities of glacial debris and river muds and sands, but as many of these rivers are lost in the desert, and only the Syr Daria and Amu Daria reach the Sea of Aral through courses which are continually changing, the amount of drift being spread over the plain must be very considerable. Some of this drift must have passed through three phases—glaciation, then river transportation, and finally it is blown by the winds during the sand-storms so frequent in the region. The names of the "sand-deserts" are significant, the Kara Kum or Black Sands in the northern part, the Kisil Kum or Red Sands between the two great rivers, and the Ak Kum or White Sands north of the great Thian Shan range. The Turkoman Desert lies between the southern end of the Aral Sea and the Caspian; the extreme north of the depression, where desert passes into steppe, is the famous Kirghiz Steppe.

In a measure the four great plains—North German Lowlands, Russia, Western Siberia, and Aralo-Caspian—are part of one great earth region, and have much in common. They are vast sunken parts of the earth's crust, where erosion and denudation have been at work for long periods of geological time; afterwards, in later Tertiary and Pleistocene times, that is, in quite recent geological periods, they have been covered in varying degree with deposits of rivers, seas, glaciers, and wind, these deposits being often intermingled and overlapping, and producing special conditions in comparatively limited regions. These great plains are often spoken of as the Great Eurasian Plain by geographers, and there is justification for this in the fact that the plain is continuous from the Wash to the Yenisei, from the White Sea to the southern desert of Turkestan, with only the very minor break of the low Urals and their

branch, the Timan range, and the small Ust Urt plateau between the Aral and the Caspian Seas

The Great Plain of North America—The build of North America is comparatively simple It consists of four chief elements (*a*) Long lines of younger fold-mountains in the west, with the crust-blocks between them, (*b*) the older and lower Atlantic mountains in the east, (*c*) between these the great plains stretching from the Arctic Ocean to the midland sea in the south, and (*d*) the Atlantic coastal plain [1] The great medial plain, or series of plains, illustrates some general principles very well, and the study of them may well follow that of the great plains of the old world We may consider five divisions, though here, as always, they often grade into each other—the Gulf Plain in the south, the prairies in the middle of the continent, the great plains or great plateaux reaching to the foot of the Rocky Mountains, the sub-Arctic Forest Plains, and the Arctic Tundra in the far north

Considering these plains as a whole, it may be said that between the older Highlands of the east and the newer Highlands of the west there seems to be a very great and shallow syncline, in which Palæozoic and Mesozoic rocks lie fairly horizontally The far north—round Hudson Bay—is an Archæan land and, in many respects, is somewhat like Finland, the far south, along the border of the Gulf of Mexico, and some distance up the valley of the Mississippi, is a region of Pleistocene and Tertiary deposits The region round the great lakes, though it lies between the north-eastern prairies and the low plains round Hudson Bay, and though it has been named the Plain of the Great Lakes, is not so much a plain as a dissected Archæan plateau

[1] Many would add a fifth element, the Canadian Shield or Laurentian Shield

This vast continental basin embraces about three-fifths of North America, it contains most of the drainage areas of the Mississippi-Missouri system, the rivers which drain to Hudson Bay and the great Mackenzie system of the far north It is possible to pass from the Arctic Sea to the Gulf of Mexico without rising to 1000 feet, though much of the continental basin reaches far above that level Still there is remarkable general evenness of surface and of structure, the only exceptions to the real *plain* character being the Lake Plateau, the Black Hills of Dakota, and the Ozark Mountains between the Kansas and Arkansas Rivers

The various sections of the great basin have characteristics dependent upon the local nature of the deposits and upon climate, many of the considerations being the same as in the case of the Eurasian plains The Gulf Plains have a basis of Tertiary strata, for the sea invaded the region as far as St Louis in Pliocene times A Pleistocene marine invasion has also spread its sediments over large parts of the plain Much of the surface of the lower Mississippi basin is mainly covered by the alluvium of the great river, which frequently overflows its banks This river and its tributaries have deposited immense quantities of silt, and have changed their courses very frequently, hence there are plenty of cut-off lakes and marshes, in which vegetation grows to intermingle its organic residue with the alluvium of the plains Sir Charles Lyell made the lower basin of the Mississippi known for all time by his clear description of the curves of the river, its crescentic cut-off portions (now called Ox-bows), its raised banks or levees, the swamps adjoining the river, and the structure of the great delta

The Gulf Plains are the home of the southern pine, which forms the basis of an important industry Many

other timber trees are also found there, and, before the advent of man, large parts of it were clothed with such a dense forest of trees and of creepers as to be practically impenetrable. It is now a region well adapted for the cultivation of maize, cotton, rice, and the sugar-cane.

The Prairie Plains.—These stretch from Texas to the Great Lakes and northwards through Minnesota into Canada. For 1000 miles one may travel northwards over these gently rolling fertile lands, which are 800 miles in width in the central part, and cover in all nearly half a million square miles, or four times the area of the British Isles. Throughout almost all their vast extent the underlying rocks are horizontal sandstones and limestones. The deposits of an ancient sea have been raised with slight disturbance into the almost flat prairie, the local variations of which are largely due to variable rock erosion, and especially to the work of streams which have cut deep valleys in the easily eroded strata. A new factor was introduced into the character of the prairie north of the Ohio River during the glacial period, for glacial ice, with its underflow of sub-glacial streams and its outflow of silt-laden water at the ice margin, has spread over the prairie deposits of glacial clay, sand, and gravel, and left huge morainic mounds and myriads of erratics here and there. The prairies are thus somewhat like middle Russia, and the subsoil of the prairie south of the ice margin is often much like the Tchernozoum of Russia, black and wonderfully fertile. The North American prairie must be traced far into Canada, however, before we find the real counterpart of the mid-Russian plain, where the sub-Arctic forest plain, with its primeval forest and its marsh, forms another division of the Great Continental Plain.

The Great Prairie Plains are now the lands of cotton

in the south, maize in the centre, and of wheat in the north The prairie region of Minnesota, Dakota, and Manitoba to-day forms one of the great wheat areas of the world

The Great Plateaux—These have been mentioned already (Chapter IV) It may be added here that they extend from the prairies of the central continental basin in a vast expanse to the foot of the Rocky Mountains They gradually rise from east to west until they reach nearly 6000 feet, but the ascent is so gradual that the aspect is one of almost unbroken monotony Too dry for much timber, and also somewhat dry for maize and wheat, these great plateaux are the great stock-rearing regions of the continent These plains are largely occupied by Cretaceous deposits, though there are also large areas of Tertiary strata, through these the eastward flowing rivers have cut their way, in some cases in deep channels, in others in wide valleys The most deeply dissected part is the plain of Texas where the rivers have cut cañon-like gorges in the Cretaceous grits and Tertiary sandstones of this dry region The "Bad Lands" of Dakota already described occur in the northern portion of the United States plateau The Great Plateaux extend into Canada, where the rivers flow hundreds of feet below the plateau surface, and hence are almost useless for irrigation purposes This, therefore, is the stock-raising region, though an extension of wheat growing is now in rapid progress

The Sub-Arctic Forest Plain.—This spreads almost across the whole northern continental basin, from the Laurentian plateau to the base of the Rocky Mountains The change in condition from prairie and dry plateau to sub-Arctic forest comes gradually, and is chiefly due to less evaporation and to the longer persistence of

water in the soil The influence of former ice-sheets is seen in the numerous swamps and lakes, and the whole region reminds one of the glaciated forest region of mid-Russia

The Tundra—In North America, as in Russia, the tundra succeeds the forest region It is a vast frozen morass, the vegetation of which is chiefly mosses and lichens, and in the short summer a luxuriant carpet of flowering plants springs up as by magic As in Siberia and European Russia the subsoil is permanently frozen to a considerable extent The rivers thaw in their upper reaches before the ice of the deltas and estuaries has melted, and there is then, as in Russia, overflowing and mingling of alluvium with the black peaty soil, the whole to be frozen in as the next long winter sets in

The Great Continental Plains are thus a vast sunken area, partly covered with Palæozoic, Mesozoic, and Tertiary sediments, which are on the whole remarkably horizontal Newer deposits by sea, rivers, wind, ice, and vegetable growth have modified the fundamental character of the region just as in Russia The north to south extension, and the diminution of the rainfall towards the west until the Rocky Mountains are reached, allow the influence of climate to reveal itself to a very marked degree

The Plains of South America—There is considerable similarity between the structure of North America and South America The southern continent, like the northern, has a great series of Pacific mountains in the west (younger folded mountains), and a series of older highlands in the east, and between these a series of vast plains The South American continental plains may be divided into three regions · (1) The plain of the Orinoco, (2) the vast plains of the Amazon; (3) the La Plata plains, including the Pampas

The plain of the Orinoco is filled with sands, gravels, etc , recent river deposits which rest on Tertiary marine strata The plains are called *Llanos*, grassy plains sloping gradually towards the sea, and dissected into mesas by the tributaries of the Orinoco Some parts of the plains are almost desert, but forest growths of tropical lowland type encroach on these grassy plains in the wetter regions

The vast Amazonian Plain rests in a wide syncline, filled with Mesozoic and Tertiary deposits The rainfall is very great, and the river brings down heavy quantities of sediment The basin has thus been filled with rich alluvium on which grows the luxuriant tropical vegetation, fed by the abundant rains The great river flows in wide-branching channels through its own deposits, in a plain which reaches to the very foot of the Andes The extent, and the level character of the plain, are shown by the position of Iquitos, 300 feet above sea-level, and 1400 miles from the mouth of the mighty river

The watershed between the Amazon basin and that of the La Plata is a very low one, comparable to that separating the Mississippi basin from the Hudson Bay drainage Immediately south of the watershed is the Gran Chaco, an immense plain where marshes and cut-off rivers abound This plain is divided into northern, central, and southern parts, each with its own peculiarities of vegetation and drainage The tropical forest ceases here, and the steppe of the warm temperate region begins In the great La Plata depression are river deposits, and a loam akin to loess, overlying Tertiary beds which in their turn seem to lie on a foundation of Archæan rocks The Pampas, south of the Gran Chaco, are immense plains with innumerable salt lakes, and rivers which often lose themselves in marshes or lagoons Some of the deposits of the plain were

probably formed in a time of greater rainfall by rivers which have now lost much of their power

The Australian Plains—These are very similar in general character to the drier prairies of North America and the Pampas of South America, and need not be further discussed here

Some Intermont Plains

The Hungarian Plain—This plain lies within the curve of the folded Carpathians, and against the somewhat abrupt termination of the expanded eastern Alps It is clearly a depressed area, with a series of fracture-lines bounding its margins The extent to which sinking has taken place has been shown by a boring near the Danube which passed through 3000 feet of newer strata before arriving at the floor of older rocks on which the deposits of the plain rest At the beginning of the Miocene period there was a sea covering much of this area The sea was gradually filled up with sediments until there were left only brackish lakes, becoming more and more salty Salt deposits of Tertiary age are the result of this disappearing sea Finally steppe conditions resulted, and deposits of loess alternated with river alluvium from the encircling mountains and the distant Alps

There are two plains, the lesser Alfold or basin of Vienna and the greater Alfold or Hungarian Plain The former contains immense deposits of gravels and sands brought down by the Danube, by the Raab from the Alps, and by the Carpathian Rivers The greater plain, the Alfold proper, has Tertiary rocks underlying 600 feet or so of Pleistocene river alluvium and semi-desert loess In some parts, especially between the rivers Danube and Theiss, there are shifting sand deposits

The continued accumulation of sediment is seen in the growing dykes which are necessary to contain the Theiss below Szegedin[1] The great Carpathian river has a fall less than that of the Danube, hence, when the latter rises considerably, as the result of the melting of the Alpine snows, the Theiss is dammed back This may be accentuated by the flooding at the same time of its two great lateral tributaries, the Samosh and the Korosh, which bring down the flood waters and alluvium of the Carpathians and Transylvanian Alps These great tributaries with their rapid flow and their enormous bulk of sediment are pushing the Theiss westward towards the Danube The river has thus been driven westward for at least 60 miles within the recent period

The typical Hungarian plains or *pusstas* have much of the true continental character of the Russian steppe More of the plain is being reclaimed for settled agriculture, and fields of maize, wheat, and beet are increasing in number at the expense of areas formerly given over to sheep, cattle, and the half-wild horses of the plain

The Plain of Lombardy.—This is part of the sunken Adriatic Gulf, filled up by sediments derived from the erosion of the Alps In the Pliocene period it was still occupied by the sea, and marine deposits of that period are found at the foot of the Alps Glaciers and Alpine torrents have combined to fill up the shallowing sea, and have succeeded so well that a boring at Modena, 6 miles south of the Po, passed through 600 feet of Alpine deposits The work of erosion and transportation still goes on, and the alluvial deposits are rapidly encroaching on the Adriatic Sea Within historic times the deltas of the Po and Adige have added most of the lagoon-bordered land between Ravenna and

[1] Now Szeged

the Gulf of Trieste The alluvial plain of the Po is thus similar to that of the Danube-Theiss , the former being of later origin however They are alike in being sunken areas filled in partly with marine sediments covered with vast deposits of river-borne material, coming from mountains where erosion is proceeding at a rapid rate

Alluvial Plains between Fold-Mountains and Crust-Blocks.—In many parts of the world, between Alpine mountains and resistant crust-blocks of older rocks, there are sunken areas which are now more or less filled with sediments derived mainly from the great mountain chains, partly from the worn edges of the crust-blocks Only a few examples of these obvious alluvial plains need be mentioned, but it will readily be seen that they include some of the most important and most fertile parts of the earth's surface (*a*) The Plain of Andalusia, or the Valley of the Guadalquivir, in Spain, lies between the folded Sierra Nevada and the Sierra Morena, which is the dissected edge of the Meseta , this is a plain which, when properly irrigated, is of great fertility, though some portions of it are marshy and malarial , (*b*) the Valley of the Rhone between the lofty Alps and the Cevennes is very similar, but quite narrow, with a mountain extension from the Auvergne plateau coming to the right bank of the river at Valence and for some distance south of that town , (*c*) the Great Plain or Valley of Mesopotamia,[1] watered by the Euphrates and Tigris, seems to lie similarly between the younger line of the Zagros Mountains and the old block of Arabia The two great rivers formerly entered the Persian Gulf separately, but they now join and form the Chatt-el-Arab, which is pushing its sediment into the Persian Gulf just as the Po-Adige is

[1] Or Iraq

filling up the Adriatic At the beginning of the last century the delta had extended itself 2 miles in about forty years Within historic times it has encroached on the gulf about 600 miles (*d*) The Indo-Gangetic plain is one of the most important plains in the world, in parts it is very thickly peopled, and is inhabited by at least 200 millions of people To the north of the Deccan platform lies the depression which is complementary to the great Himalayan fold The two great river systems, the Indus and the Ganges, are continually bringing down enormous quantities of sediment Borings in the delta of the combined Ganges and Brahmaputra show river deposits to a depth of 500 feet, and indicate the immense amount of deposition which has taken place in the trough between the young fold-mountains and the old resistant block of Peninsular India

A Typical Coastal Plain—The North America Atlantic Coastal Plain.—In eastern North America there is a remarkable coastal plain extending from New York to the Gulf of Mexico, and this may be briefly studied as a typical example The 100-feet contour line is approximately the landward boundary of this plain, and the numerous rivers from the Appalachians descend in waterfalls at this level to flow as navigable rivers across the lowland Many of the rivers form broad tidal estuaries At the fall-line limit there occurs a series of well-known towns—Trenton, Philadelphia, Baltimore, Washington, Richmond, etc The plain continues beyond the shore line as a shelving coast for some distance outwards, until a sudden drop is reached where the " continental shelf " ends and the real Atlantic Ocean begins The submerged continental shelf and the coastal plains may be regarded as parts of the same land-form

The inland limit of the coastal plain is a sharp

boundary line between older rocks and strata of late Mesozoic and Cainozoic age, which form the basis of the plain Resting on these are alluvial deposits brought by the numerous rivers Under the shallow water of the continental shelf are deposits of continental origin, sand and clays chiefly Clays occur in plenty in the submerged estuaries which are continuations out to sea of those on land The whole structure tells of a sunken coast with drowned river-valleys now forming tidal estuaries

The plain is mainly constructive in origin—that is, it is formed of deposits, marine and alluvial, according to circumstances, but there is little doubt that tidal erosion has also played a part in cutting back cliffs and planing down the land, and so to a smaller degree the coastal plain is a plain of marine denudation

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The Continent of Europe L W LYDE Macmillan & Co May be consulted for all the European plains 10s

Compendium of Geography and Travel STANFORD 13 volumes 15s each This large work contains the fullest description of the countries of the world that is readily accessible to English readers

See also the Bibliography of Chapters I to V, also *The Thirsty Earth*—E H CARRIER Christophers—where the part played by irrigation in most of the world's plains is discussed

NOTE ON THE RECLAMATION OF THE ZUIDER ZEE

During the past eight years the engineers of the Netherlands Government have been actively engaged in carrying out one of the most stupendous works which have ever been attempted in any part of the Great European Plain —a work which will possibly require thirty more years for its completion, this is the reclamation of nearly half of the Zuider Zee or South Sea that great shallow inland sea which lies to the south of the Frisian Islands The Zuider Zee as we know it to-day, is a feature of modern times In the Roman times there was a large fresh-water lake, called Lake Flavo by Tacitus and Pliny In the twelfth and the thirteenth centuries, chiefly, there were years of high tides and storms, with north-westerly winds, the banks were broken and large areas were engulfed, until by about 1400 A D the Sea had taken on much of its present form and extent

The Zuider Zee of our day is about 85 miles long, with a maximum width of 45 miles, and covers an area of a little over 2000 square miles The Dutch engineers aimed to reclaim about 850 square miles, or nearly half the present area, the reclaimed area is a little larger than Leicestershire A main dike or embankment, fitted with the necessary sluices and locks, will extend across the opening from the island of Wieringen to the Frisian coast, almost midway between Makkum and Workhum Four separate polders will be enclosed, named respectively north-west, south-west, south-east, and north-east, and in the middle there will be left an estuarine lake, Yssel Meer, into which the river Yssel, one of the old mouths of the Rhine delta system will discharge itself

Work on the scheme proceeded vigorously since 1925, and the dike was opened for traffic in September 1933 In all it is about 26 miles long and carries a cement road, a bicycle track, and has room for a double track railway There are ten drainage sluices and two locks, each of which allows ships up to 2000 tons to pass through to Yssel Meer

CHAPTER VII

LAND-FORMS VALLEYS AND BASINS

VALLEYS are of great variety of form and origin, but, broadly speaking, it is convenient to divide them into two great classes —Tectonic Valleys, which are immediately due to movements in the earth's crust, and Erosion Valleys It is quite possible, indeed it is highly probable, that many valleys which are regarded as valleys of erosion are partly tectonic In this respect valleys are quite like other earth-features, difficult to classify rigidly

TECTONIC VALLEYS

These may be divided into two sub-classes (*a*) Valleys in downfolds of rocks, or Synclinal Valleys , and (*b*) Fault and Rift Valleys

Synclinal or Downfold Valleys —It has already been stated that the earth's crust has been thrown, in many regions, into a series of folds, trough-folds or synclines and arch-folds or anticlines, and examples of these have been mentioned It is obvious that in a series of such folds the synclines must tend to form valleys, and many such valleys are seen in different parts of the world

The syncline of the Cretaceous and Tertiary rocks of the London basin was mentioned in Chapter IV. This basin is often described as the lower Thames *Valley*, though perhaps, in ordinary language, the two

names do not connote quite the same thing, the basin is probably usually considered to be more extensive than the valley, and to include it

There are many such synclinal basins, but it is not always the case that a river runs for a considerable distance along the " axis " of the downfold as the Thames does from Reading to the sea The following are British instances where the rivers do flow axially The Vale of Pickering is a very shallow basin, extending from east to west between the Howardian Hills, the Wolds, and the Tabular Hills of the North York moors The Lancashire Calder, from Colne to the Whalley Gap, has the main stream flowing along the syncline of the Burnley coal-field The valley of the Frome in Somersetshire is another example The valley or basin of the Ebro (or the Aragon depression) in Spain is a synclinal basin of Mesozoic and Tertiary strata The depression is bordered on the south-east by the Catalonian Mountains, through which the Ebro has cut its way in a fine transverse gorge

A longitudinal valley-basin extends between the two chains of the Atlas, which is apparently of the same type as the Upper Rhone and Vorder Rhine valleys between the middle and northern Alps This long valley system contains Jurassic and Cretaceous rocks thrown into folds, and may be described as a synclinal valley The lower parts of this trough contain salt-lakes, known as *Shotts*, the region is one of very low rainfall Some parts of the valley contain thick deposits of Pleistocene age, derived from the weathering of the high mountains of Alpine type during an age when rainfall was more abundant than it is to day

There is a somewhat similar longitudinal valley in North America—a long, narrow trough—which is

probably very similar in structure to the valley of the Shotts This occurs between the Pacific Coast ranges and those of the Sierra Nevada and Cascades The valley of San Joachim, the Sacramento valley, and Puget Sound are probably all parts of this downfold valley. A good deal of faulting has accompanied the folding, and there is plenty of evidence that this portion of the earth's crust has not yet reached anything like a stable condition

The Sacramento valley has been largely filled with fertile alluvium, and it forms a veritable garden of the west The San Joachim and Sacramento Rivers unite and flow into the Pacific through the transverse Golden Gate at San Francisco, where the coast range is cut at right angles. Somewhat more to the south the salt lake Tulare, in a limited region of internal drainage, reproduces some of the features of the Shotts of the Alfa valley of North Africa

The folding of great Alpine systems often produces longitudinal valleys extending along the strike or trend of the strata Professor Bonney long ago pointed out that the valley of the Rhone above Martigny was originally a synclinal fold of softer rocks extending lengthways between the Bernese Oberland and the Pennine Alps The valley of the Vorder Rhine from Chur up to its end at the foot of the Oberalp Pass is similar in structure to that of the Rhone, and needs only this brief mention here

A magnificent series of folded valleys occurs at the eastern end of the Gangetic Plain of India, where the Yang-tse, Mekong, Salwen, and Irrawadi run in mighty longitudinal folds between the great parallel mountains Similarly the Drave and Save flow in the synclinal basins formed by the opening out of the eastern Alps

Some of the rivers of the Jura run for long distances

as longitudinal rivers, along the axes of synclinal folds formed in that Alpine foreland It is said that there are twenty such parallel folds in the Jura, and the rivers which run along their troughs break through in transverse *cluses*, which are, in the main, the routes through from the Rhone-Saone to the Swiss plateau

Prof J B Jukes pointed out long ago that the rocks of Southern Ireland have been thrown into a series of parallel folds whose axes run east and west The longitudinal stretches of the Bandon, Lee, and Blackwater run along these folds, and then turn off in transverse gorges at right angles to their earlier courses Jukes's paper, written in 1862, was probably the first systematic survey of a series of river-valleys from the genetic point of view

It will appear from a consideration of the examples discussed above that the terms valley and basin have not always a very definite connotation We speak of the "Vale of Pickering," but seldom of the valley, it forms a very shallow valley or basin In North-East Lancashire, "Burnley Basin" or "Calder Basin" is used quite as frequently as Calder Valley, and yet, as in the case of the London and the Thames, the valley and the basin are not quite the same

Synclinal basins on a large scale—that is, where there is a shallow downfold in which newer deposits have been accumulated—are quite numerous, the Paris basin is a well-known example

The Mississippi basin is probably an enormous shallow syncline stretching from the western slopes of the Appalachians to the eastern slopes of the Rocky Mountains There are many other examples of tectonic basins in different parts of the world

Fault Valleys and Rift Valleys or Trough Valleys. —This part of the subject also may be best illustrated

by examples The Vale of Eden may be taken as the first type The great Pennine Fault was mentioned in Chapter V It forms a magnificent scarp from the edge of which the observer looks westward over the fertile Vale of Eden, with its patchwork of cornfields and meadowland, and numerous plots where the red soil of newly ploughed fields shows in striking contrast Farther west rise the hills of the dissected dome of the Lake District The rocks of the Vale of Eden are Triassic and Permian (together called the New Red Sandstone), and are newer than the rocks forming the

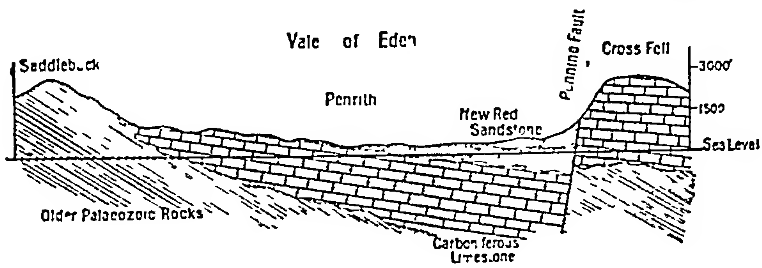

FIG 16—A DIAGRAMMATIC HORIZONTAL SECTION FROM SADDLEBACK TO CROSS FELL ACROSS THE VALE OF EDEN, TO SHOW THE RELATION OF THE ROCKS TO THE PENNINE FAULT

Cross Fell plateau, which are Carboniferous The same Carboniferous rocks are seen on the eastern edge of the Lake District forming the partial border already mentioned (*see* Geological map, Fig 10) These dip under the New Red Sandstone marls and sandstones of the Vale of Eden The general structure and relation to the fault is best seen by a section (Fig 16)

Thus the Vale of Eden is a fault valley or wedge-shaped basin, and the sharply contrasted geographical regions—the Cross Fell plateau, the vale itself, and the Lake District dome—are obviously due to the relation of the different rocks to the great Pennine Fault already mentioned

The Vale of Andalusia or Guadalquivir Valley is very similar in structure It lies between the Alpine Mountains—the Sierra Nevada, and the faulted edge of the Meseta, known as the Sierra Morena This valley has already been described as an alluvial plain, thus forming another example of how land-forms grade into each other insensibly

A very fine example of a valley due to fracture, but not a rift valley, as generally understood, is the Great Glen of Scotland This magnificent natural trench extends in a perfectly straight line for 100 miles, right across the country from the Firth of Lorne to the Moray Firth The bottom of this glen is never more than 100 feet above sea-level, but the deepest part is nearly 800 feet below the surface level of the sea In the deeper parts of this straight trench lie the lakes Lochy, Oich, and Ness, the latter nearly 20 miles long and less than 1 mile in width Many of the other Scottish glens, some of them forming sea-lochs and some containing long, ribbon lakes, lie in fracture-trenches, having the same general direction An inspection of a good orographical map shows a whole series of valleys strictly parallel to Glen More, another series is almost at right angles and also contains fiords and inland lakes The Scottish plateau was evidently shattered by a double series of interlacing fractures, probably at the time when the North Atlantic was formed and Scotland was separated from Scandinavia The fracture-trenches are the famous Scottish glens Some of these glens may be simply deep river-worn valleys, but it is almost inconceivable that so many of them should lie in definite directions, the same directions as that of known fractures, unless they are associated with faults which follow the same direction but are not apparent at the surface The fiords of the

western coast of Scotland are probably drowned valleys of this type (*see* Chapter VIII)

The Rift Valley of the Rhine was discussed in Chapter IV This is an admirable example of a valley formed by a pair of roughly parallel faults letting down the region between the two horsts The bottom of the valley is a plain of considerable extent, 200 miles from south to north, and roughly 20 miles in width

A most interesting rift valley, or linear series of rift valleys, extends from the north of the Dead Sea to the Zambesi region in Africa, and includes the Gulf of Akaba, the Red Sea, and the basins of Lake Rudolph and Lake Nyassa This line of depressions extends for 3000 miles, and marks one of the most distinctly fractured parts of the earth's crust It ends off abruptly against the Taurus range of Asia Minor The Lake of Tiberias, the Valley of the Jordan, the Wadi-el-Arabah, the Gulf of Akaba are obvious parts of it in the north Lake Tanganyika occupies a similar linear depression, which appears to be related to the series of fractures mentioned above

The basin of Utah, Nevada, and Oregon is another example of a sunken portion of the crust due to a series of fractures In this region evaporation keeps pace with the small rainfall, and many of the various lakes which exist in the hollow have no outlet, and are therefore salty

Lake Baikal in Central Asia occupies a fault basin Its surface is 1560 feet above sea-level, but it is so deep that its bottom is more than 3000 feet below sea-level It is the deepest of all the continental depressions Its very steep walls are probably fault scarps, formed in comparatively recent times, and the existence of volcanic craters in the neighbourhood, and the

frequency of earthquakes, show that the crust is still in an unstable condition

Spencer Gulf in South Australia is yet another example of a valley due to subsidence between two lines of faults, it is a "rift-valley" similar to that of the Rhine St Vincent Gulf is probably a similar subsided region

The Central Valley of Scotland—generally known as the Lowlands—is another well-known example of a rift valley, of which the width is relatively great A great north-western boundary fault divides Strathmore from the Highlands, and a nearly parallel series of faults separates the Southern Uplands from the Midland Valley The northern fracture-line stretches from near Aberdeen to the Isle of Arran, the southern series of fractures from near St Abb's Head to Ballantrae The southern system of faults is not so well defined as the Highland boundary fault Between these two parallel fault-systems the Palæozoic rocks of the Midland Trough were let down, and probably in consequence of the subsidence, masses of volcanic rocks were extruded at various points along a direction roughly parallel to the general north-east and south-west trend of the faults These volcanic rocks have resisted denudation better than the Old Red Sandstone and the Carboniferous sediments of the Lowlands, and there are four groups of hills separated by the great rivers which cross the "Rift Valley" The Sidlaws, Ochils, Campsie Fells, and Renfrew Heights are the hills referred to, they extend serially along a line which is roughly parallel to the great boundary fault

The Midland Trough or Rift Valley is thus an example of a tectonic depression of very great geographical importance because the majority of the Scottish people

are located on its fertile lowlands or its industrial regions It is variously described as a valley, a basin, and a trough There is something to be said in favour of the use of each of these , perhaps least of all for the name "valley" It is clear, however, that we have here another illustration of the difficulty of using a definite series of names, each with a limited meaning The difficulty is inherent, because these different sub-types of land-forms grade into each other quite insensibly It seems inadvisable to insist on a rigid connotation in this as in other departments of descriptive natural science

There are many similar rift troughs or valleys in different parts of the world An interesting modification is found in Nevada where cañon-like valleys occur, which are obviously due to subsidence These were at first mistaken for cañons of the Colorado type, that is, cañons due to erosion by rivers acting on approximately horizontal strata in a dry region

VALLEYS OF EROSION

Many valleys of this type were necessarily mentioned in Chapter V , in discussing the dissection of elevated land-forms, and some of the different sub-types were foreshadowed These forms illustrate Prof Davis's principle that all land-forms are functions of structure, process, and stage That is, their present condition depends firstly upon the nature and relationship of the rocks out of which they were formed , secondly, upon the processes at work , and thirdly, the time these have been at work, and the stage in the operation which has been reached

Cañons.—This is perhaps the most striking sub-type Cut deep in horizontal strata, with vertical or almost vertical walls often extending for great distances, these

earth trenches form very striking examples of young valleys Horizontal, or nearly horizontal, strata are the first requisites, with the joints which are found in all rocks The second consideration is that down-cutting predominates over lateral cutting, this is due to the climate, but is partly dependent upon the velocity of the stream and the extent to which it is armed with cutting tools in the form of sand grains Thirdly, the uplift is comparatively modern, and the gorge is still in the young stage It must, however, be remembered that given similar rocks in a region where the atmosphere contains much more moisture, the lateral weathering may cause the river gorge to assume a much more advanced stage

The type cañons of the world are, of course, those of the great plateaux west of the Rocky Mountains The Grand Cañon of the Colorado is described in most books of Physical Geography and referred to in almost every text-book of Geology It is more than 200 miles long, its width varies from 5 to 12 miles, and it is nearly 6000 feet deep The upper part is often much less steep, and was evidently cut when the atmospheric conditions were different, and lateral weathering was more in evidence The lower part is in places bounded by vertical walls of great height

As already mentioned, cañons are found in other parts of North America, especially in the great region of plateaux between the Rocky Mountains and the mountains bordering the Pacific Coast The nearest approach to these in grandeur are the deep trenches of the Southern Abyssinian plateau briefly mentioned in Chapter V

Gorges —There is no hard-and-fast line dividing the gorge from the cañon In general it may be said that a gorge is a small cañon Gorges are cut by rivers in

horizontal strata where especially pronounced jointing facilitates this process, as was instanced by the gorges of the Loess, the Quader-Sandstein of the Elbe, the Tarn, and the limestone gorges of the British Carboniferous

Transverse River Gorges—Deep river gorges of a more irregular character are often found where a river runs transversely to a young mountain chain The Alps abound in magnificent examples Many of the feeders of the Rhine and Rhone come from the inner parts of the Alps in a direction roughly at right angles to the trend of the mountains, and in almost every case a deep gorge has been cut out by the debris-laden stream The fine gorges of the Schyn and the famous Via Mala on the Hinter Rhine system are examples from the east of Switzerland, the Schollenen gorge of the Reuss and the renowned Aar Gorge are well-known examples from Central Switzerland, the grand gorge of the Trient, near Vernayez, may serve as an example from the Western Swiss Alps Of course there are many more in the Alps, the above are well known and are easily reached from tourist centres

The Indus cuts the western end of the Himalayas transversely in a series of gorges which are said to be almost impassable The gorges of the Brahmaputra at the eastern end of the same mountains are so stupendous and so difficult of access that the course of the river was marked by dots on maps which are yet in common use The Yang-tse-Kiang runs for some time concordantly with the trend of the folded mountains already mentioned, then it cuts across them, and its transverse gorge is one of the finest in the world

To refer to the Rhine and Rhone again Both rivers run for many miles in longitudinal troughs, the

PLATE XI.—THE VIA MALA, A TYPICAL TRANSVERSE GORGE IN THE RHAETIAN ALPS. THE HINTER RHINE CUTS THROUGH TO JOIN THE VORDER RHINE

valley of the Vorder Rhine continuing the direction of the Rhone lengthways between the line of the middle Alps and the long line of the Bernese Oberland and the Todi Alps Each river then cuts across the outer range from its inner Alpine trough the Rhone at Martigny, the Rhine near Sargans These transverse valleys are, however, comparatively wide, though that of the Rhone is clearly a trench cut right through the Alps, thus separating the Chablais Alps from the western Bernese Oberland The Diablerets and the Dent de Morcles are obviously the same in structure and belong to the same system as the Dent du Midi on the southern side of the Rhone

There are many other transverse gorges of great interest but of somewhat different type The Rhine from Bingen to Bonn trenches across the European Mittel-gebirge, a comparatively shallow gorge cut in a plateau of ancient rocks The Meuse from Givet to Namur cuts across the Ardennes massif similarly The uplift of the Ardennes-Eifel-Westerwald plateau has been comparatively recent The river seems to have been in existence before that uplift and to have cut down as fast as the block was raised, so that the Rhine of the Rift Valley was apparently not converted into a lake The river was antecedent to the uplift, but we must be careful not to assume that every case of a transverse gorge is due to an antecedent river cutting down through a later uplift

The transverse river gorges just mentioned are of very great importance in connection with the movements of man In peace and in war, in mediæval times and in modern trade, they have provided the routes by which man has travelled The sides of the gorge of the Rhine are crowned with mediæval castles,

and its every point bristles with interesting mementoes of the march of armies and the passage of traders

The typical cañon of the arid plateau, the gorge through jointed limestones and sandstones, and the transverse gorge through folded mountains or incised in a plateau uplift have one feature in common they are U shaped valleys of varying acuteness, such as may be diagrammatically represented by such forms as the following

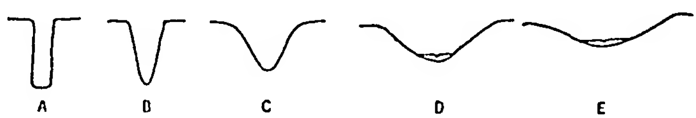

FIG 17 —DIAGRAMS OF VALLEY FORMS

A Very young stage, cañon or similar gorge B Young stage, shoulders still angular, V shape acute C Adolescent stage, shoulders rounded, V-shape much less acute D Mature stage, alluvial deposit forming in the broad bottom of the mature valley E Old age form, very shallow valley, with alluvial deposits of greater extent

In the shallower ones lateral cutting has been proceeding for a long time, and so the river only appears as a narrow streak in a broad-bottomed valley The Rhone gorge from Martigny to St Maurice is a good example of this type Transverse valleys are valleys of erosion, but longitudinal valleys are often not valleys of erosion in the same sense, many are synclinal valleys with a long extension, following, as the geologist says, the strike of the strata Longitudinal valleys occur in regions of folded mountains, the river running more or less parallel to the direction of the folded beds Thus the Rhone and its valley are longitudinal, between the parallel Pennines and Bernese Oberland from the Furka Pass to Martigny So the Rhine is

longitudinal from the foot of the Oberalp Pass to Chur. There are good examples of longitudinal river valleys in the Jura, where the series of comparatively gentle folds allows of the ready production of such valleys. Many rivers are by turns longitudinal and transverse, a good example being the Doubs.

The upper Indus occupies a longitudinal valley on the northern side of the Himalaya; the upper Brahmaputra runs for hundreds of miles in a great longitudinal valley between the Himalaya and the trans-Himalaya or Tibetan Himalaya. The longitudinal valleys of the great river system of further India and Indo-China have already been mentioned.

These valleys offer routes for penetration right into the heart of mountain countries. Thus the long reaches of the upper Rhone and the Vorder Rhine have directed many movements of people in the Alps.

Anticlinal Valleys.—The summit of an anticline clearly offers itself to attack by weathering agents. Cutting down begins and continues with relative rapidity, and in time a kind of longitudinal " valley " may be produced with its long axis extending along the upfold of the rock. The Weald is not a valley in the strict sense, but is a sort of shallow basin area produced by the cutting down of the anticline (*see* the description and section in Chapter IV.). Murchison long ago pointed out the existence of such valleys in the Silurian strata in Shropshire, where the summit of the Woolhope anticline has been dissected away and a valley produced. The middle Ribble of the Clitheroe district runs along the upfolded strata of an anticline, the long-continued dissection having cut down through the Coal Measures, Millstone Grit, and Upper Carboniferous Limestone, until beds almost at the base of that series are revealed.

Similar longitudinal valleys, following the direction of dissected anticlines, are found in the Jura, in southern Ireland, and in the Appalachian region, in which many of the valleys are of the more normal synclinal type

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CHAPTER VIII

LAND-FORMS LAKES AND LAKE BASINS

There have been many classifications of lakes proposed, almost all of them from a genetic point of view Whilst it is possible to classify very many lakes without much hesitation, there are many of mixed origin, and in the case of some of the most important lakes of the world there is still sharp controversy regarding the mode of origin Prof W H Hobbs enumerates no less than 28 types, while Prof W M Davis has reduced lakes to three great groups It would seem that from the point of view of the geographer as interpreted in this book the following classes include most of the lakes of importance

1 Relics of comparatively recent seas
2 Undoubted tectonic basin-lakes
3 Lakes produced by the damming of normal drainage by some kind of deposit or other impediment
4 Solution lakes
5 Crater lakes

Relics of Recent Seas—Imagine a portion of the ocean which has been cut off by local elevation and at the same time, and perhaps partly in consequence of the tectonic changes, becoming drier, this cut-off sea may dwindle in area until it is only comparatively a relic of the ocean basin or Mediterranean Sea from which it has been derived Such relict seas are the Caspian and Sea of Aral, possibly also the Salt Lakes of

Central Australia, and such lakes as Tchad in Equatorial Africa. The Caspian still contains seals, fishes, and mollusca, which show its former connection with the Arctic Sea. There is little doubt that it once communicated with the Black Sea also. Such inland seas would, as may be expected, vary considerably in size both in successive years and from one season to another.

In the recently uplifted coastal plain of south-eastern North America there are very shallow lakes which correspond to shallow depressions on the sea floor. They are gradually disappearing owing to the accumulation of the debris of aquatic vegetation. These latter, of course, in no way depend upon an arid climate as do the seas in the mid-continental low plains.

Tectonic Basin-Lakes.—The existence of these lakes has been mentioned already in dealing with rift-valleys and with negative or depressed crust blocks. In many of these depressions there exist portions which are lower than the general or average level, and in these basins water accumulates and permanent lakes result. The Dead Sea of Palestine occupies a very deep hollow in the narrow Syrian part of the great Nubian rift-valley. The deepest part of the Syrian depression is about 2500 feet below the surface of the Mediterranean Sea. In an earlier period, when there was a greater rainfall, it partially overflowed to the Gulf of Akaba; now it is a small basin with water of high salinity, and well deserves its name, the Dead Sea.

The series of salt lakes on the East African plateau, of which Lake Rudolph is the best known, are in the same rift-valley, and also the fresh-water Lake Nyassa, which drains southward to the Zambesi. Lakes Tanganyika, Kivu, Edward, and Albert are tectonic lakes occurring in another rift-valley which is probably connected with the East African one.

Salt Lake in Utah is of a similar origin and has similar relationships It is the residue of a once great fresh-water lake, but owing to the increasing aridity of the climate it is now a salt lake and receives the drainage of an enclosed tectonic basin There are many other salt lakes in the same region

Lake Baikal is a tectonic basin lake, the deepest known lake basin in the world (*see* Chapter VII)

Lake Balaton in Hungary is a deep part of the Hungarian depression, and may be regarded as a relic of the old Hungarian Sea , it is thus partly a tectonic lake and partly a residual lake

The lakes of the Great Glen of Scotland and many other Scottish lochs are almost undoubted examples of lakes in tectonic basins, and it is highly probable that many other lakes are of similar tectonic origin

Lakes due to Damming of Normal Drainage— Lakes of this general class are very numerous, and there are many sub-classes, as there are many ways of holding up rivers and thus forming lakes The moraines of glaciers frequently extend across a valley and form a lake by damming up the river Many of the lakes of Scotland, the Lake District of England, and other recently glaciated regions have moraines at the end, and are therefore partly, at least, of this class , but in some cases they are also probably in part rock basins due to fracture Some writers say that at least ninety per cent of the lakes in recently glaciated regions are of this kind

Glaciers themselves frequently dam up rivers , the best-known European example of this is the great Aletsch glacier of the Alps, which dams up a river and forms the Marjeelen See Similar glacier-dammed lakes are found in other Alpine regions Such lakes were probably of frequent occurrence in the British

Isles in the Pleistocene glacial period, for there are undoubted evidences that glaciers extended across valleys, or opposed their fronts to the normal drainage of pre-glacial times The famous Parallel Roads of Glen Roy, near Ben Nevis, in Scotland, are now believed to be lake terraces formed at different levels by the successive lowering of a lake dammed up by a glacier which extended across the lower end of the valley These old terraces were long a source of difficulty to geologists and geographers Many British north-country valleys show some traces of old lake terraces, but these are seldom or never so well developed as in Glen Roy and some of the neighbouring valleys

A landslip or rockfall may fall athwart a mountain valley and thus impede the normal drainage, and a lake may result This may obviously happen most frequently in Alpine regions where great rockfalls are of frequent occurrence Such lakes will clearly be of a temporary character, the obstruction will soon be cut through Well-known examples have occurred at Bellino in North Italy, in Carinthia, and in the Upper Ganges valley Ox-bow or cut-off lakes of rivers may be included in the present wide class A river forms a meander or loop which brings it back almost upon itself The narrow neck of land between the two ends of the loop is burst through at a time of flood, drifted material shuts off the old curve and a loop-lake or cut-off lake is formed Almost all large rivers flowing along alluvial plains have formed these curved ox-bow or loop-lakes They are usually fairly shallow with deeper parts on the convex side, as would be expected from their manner of formation. The ox-bow lakes of the lower Mississippi are famous Similar lakes are known as *billabongs* in Australia, where they are well developed on the Murray

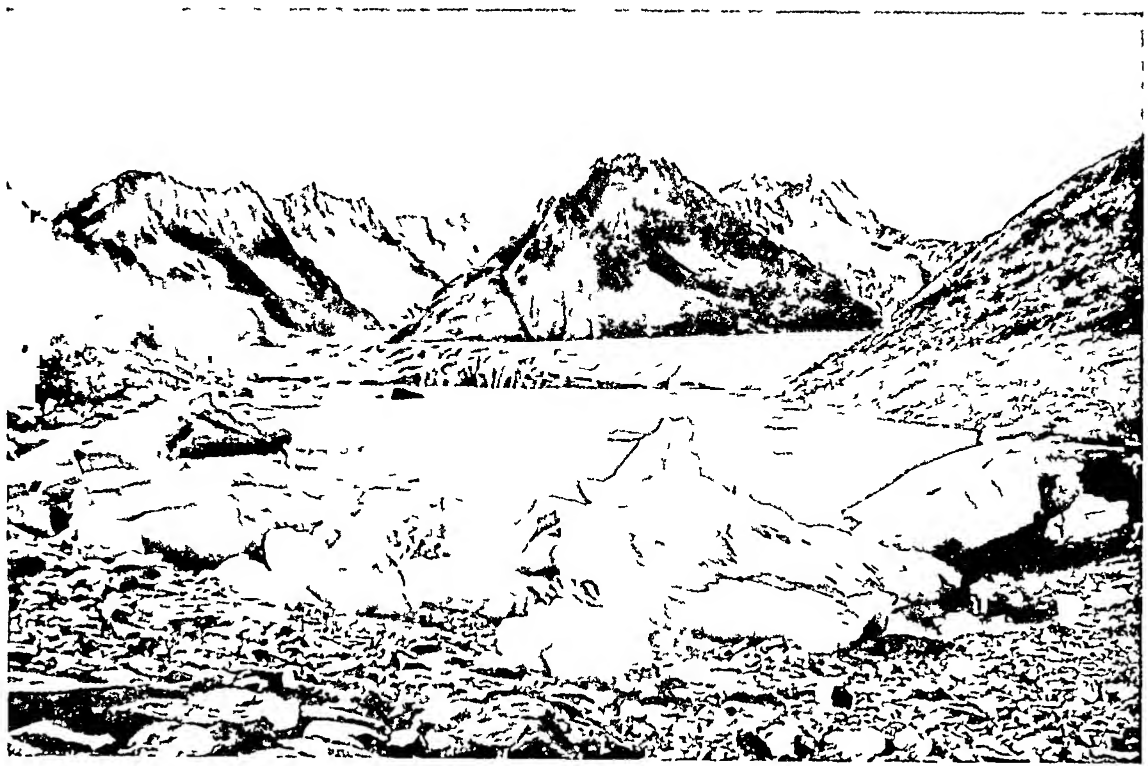
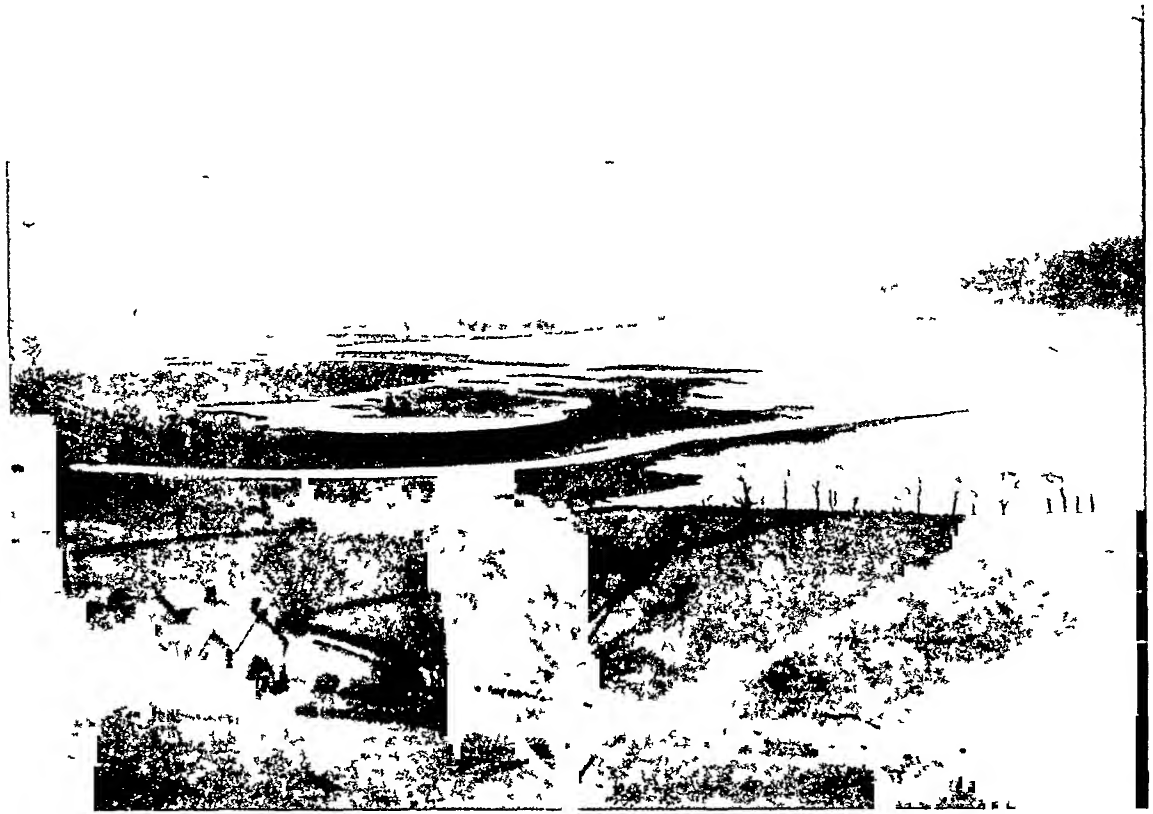


PLATE XII.—MARJELEN SEE AND ALETSCH GLACIER



[By courtesy of J Ranson, Esq F G S

PLATE XIII —ALLUVIAL FLAT BETWEEN LAKES DERWENTWATER AND BASSENTHWAITE ENGLISH LAKE DISTRICT

Very closely related to ox-bow lakes are the lakes outside the raised banks or levees of large rivers, and formed either by overflow from the river or from tributary drainage which is unable to join the main stream because of the raised banks. These are numerous on the lower Mississippi, on the Ganges, the Po and many other rivers which have well-developed alluvial plains.

Lakes formed within deltas are somewhat similar in origin. The distributaries of the river pile up mud banks, the union of two of which may enclose sheets of water. The great lakes near New Orleans, the delta lakes of the Po and the Danube are examples.

The famous Broads of Norfolk are shallow fresh-water lakes with ill-defined banks of sedges, rushes, and other water plants. The sluggish Norfolk rivers originally emptied into a wide estuary, which the drift of material has closed. The tides sweep much material along from the rapidly dwindling coast near Cromer and from the more distant coasts of Lincolnshire and Holderness. First spits of land would be formed, then deposits of river sediment would break up the estuary into irregular channels, and portions would be partly cut off by the rapid growth of water-vegetation. These ponds are of very recent origin, and are already rapidly diminishing in depth and area, partly by deposition of ordinary sediment and partly by the accumulation of vegetable debris from the luxuriant growth of marsh-plants.

Lagoons on low coasts, which are dammed up by sand dunes, are common in many parts of the world. Those of the Great European Plain have been mentioned already. In south-west France the lagoons of the Landes are of similar character and origin. Another series of such lagoon lakes is found in south-west Russia along the shores of the Black Sea.

Raft Lakes are due to the accumulation of drifted vegetation, which in time dams back the river. The most famous are those of the Red River of Arkansas and Louisiana. The raft forming one such "lake" has recently been removed to some extent, and precautions have been taken to prevent its re-growth. The White Nile, in the Sudan, is dammed up in the same way by the *sudd*, and wide marshes are formed where a great deal of the water of the river has been lost by evaporation. This impediment is also being removed so as to recover some of the land, reduce the tendency to malaria, and to conserve the water of the Nile.

It remains to be mentioned that the barrier to the normal flow of a river may be a lava-flow which dams back the water and forms a lake. Some of the famous lava-flows of Iceland in 1783 flowed athwart the Skaptar and its tributaries and formed lakes. Snag Lake in California and Lake Tiberias in Palestine are other examples.

There are other ways in which barriers may interrupt the normal drainage of a river, but the above are the most important types. The student will readily understand that all these "barrier" lakes must be relatively short-lived. They are mere episodes in the long geographical history of a region. Whether the barrier be rockfall, glacial moraine, ice, blown sand, river deposit, or vegetation, it is obvious that the outflowing river will tend to cut through it, and so drain off the lake.

Solution Lakes.—Many rivers flow over limestone rocks. To take the rivers of Central Ireland as an example, these flow slowly across the plains and they are laden with peaty matter, and consequently contain organic acids. The river water thus dissolves some of the limestone and forms irregular river expansions of

no great depth and of very irregular outline Morainic matter left by the glaciers of the Pleistocene Glacial period assists in damming up the water, and the etching effect of the peaty water, with its organic acids and dissolved carbon dioxide, is seen in the irregular surface These lakes are thus, partly at least, composite in origin

The wonderful limestone region of the Karst, to the north and east of the Adriatic Sea, shows everywhere the results of solution of the Mesozoic limestones The whole surface is fretted and etched by the solvent action of the fiercest rains of Europe Here and there are funnel-shaped openings, where the solvent water has eaten its way down through some crack or joint, and through which the water now finds its way to the underground drainage so characteristic of the district Sometimes these *dolines* are stopped up by fine sediment at the bottom and a temporary lake-bowl results The larger and more irregular sunken parts are probably small rift-valleys These are called *Polyen* In the wet season these may be covered with water, which rapidly disappears, however, in the hot summer The soil that has been washed into these sunken basins is very fertile, and consequently these depressions are relatively thickly peopled The swamps which are common in these basins, are, however, fever-laden, and as they are ill-ventilated the fertility of their soil is largely discounted Lake Zirknitz is perhaps the most famous of the seasonal lakes of the Karst land It is usually dry in late summer and autumn, and reaches its maximum depth on the melting of the snow in spring Lake Janina in Epirus and Scutari in the Montenegrin mountains are permanent lakes probably of similar origin

Crater Lakes —In many volcanic regions the craters

of dormant or extinct volcanoes are occupied by circular lakes Lake Avernus, near Naples, is the classical example There are others on the famous Phlegræan Fields In Central Italy, the lakes Nemi, Albano, Bolsena, Bracciano, and others, in the Auvergne, Lake Pavin and others, in the Eifel, the Laacher See and the other "Maare" of that region of extinct volcanoes, these are well-known European examples Lake Gustavila in Mexico is a large lake of this type "Crater Lake," in Oregon, has a diameter of over five miles There is a lake in the crater of Poas, in Costa Rica, from which steam and mud are ejected at intervals. There are crater lakes in the dormant or extinct volcanoes near Lake Nyassa and associated with the East African rift valley In the crater of Soufriere in St Vincent, West Indies, there was a small lake before the eruption of 1902, and similarly before the classical eruption of Vesuvius in A D 79, a lake had been formed in the crater of Monte Somma

There is little dispute about the origin of the classes of lakes discussed up to this point, but there are many which are not so easy of explanation and about which there has been much difference of opinion, and the points in question are by no means yet settled The following are some of the lake types in dispute

(*a*) Rock-tarns, chiefly in mountain regions
(*b*) Glen or ribbon-lakes in mountain regions
(*c*) Such lakes as the fresh-water lakes of North America

Rock-Tarns are generally small lakes lying in rock-basins in mountain regions They often seem to be quite independent of fracture lines, and their sides are almost always glacier-worn These rock-basins are generally believed to be independent of subsidence and

to be due to powerful erosion Many geologists have unhesitatingly put them down to the gouging action of ice, though this explanation would not be accepted by all There are hundreds of them in the Highlands of Scotland, and they are especially numerous in the Island of Lewis, where in some parts the map shows almost as much water as land Finland and the Laurentian plateau (or peneplane) are dotted over with similar rock-tarns

Loch Coruisk, in the Island of Skye, has been carefully studied by Harker He has shown that the whole basin is clearly surrounded by rock except for a gravel deposit at the upper end, and that the bottom is bare rock also The rock is gabbro, a rock of much toughness and durability This hard rock has been ground smooth, polished and striated, and the hardness enables the gabbro to retain all the marks of glacial action with a freshness which makes it difficult to realise that the ice departed many thousands of years ago

Among British lakes in other localities Thirlmere and Watendlath Tarn in the Lake District, and Cwellyn and Glaslyn in Snowdonia, have been considered to have a similar origin

Glen Lakes, or Mountain Ribbon-Lakes—These include the longer and larger lakes in the Highlands of Scotland, and the great valley lakes of the Alps and of Alpine regions generally This type has given rise to much discussion One school of geologists, following Ramsay, has taught that they have been scooped out by ice, and for a long time this was accepted A later school of geologists has taught that glaciers cannot erode rock-basins So the question of the origin of these lakes has been merged in the general question of ice-erosion

The truth probably lies between the two extreme views Many of the Highland glens of Scotland are primarily tectonic in origin River action continued for long ages has cut deeply into the table-land of hard rocks During the glacial period weathered material was carried down by the glaciers, some protruding rock-masses were removed, and smooth striated surfaces were imparted to many of the rocks Moraines were accumulated in some of the lower parts of the valleys Perhaps during the recent change of level, of which there is abundant evidence in Scotland, there was sufficient warping or irregular tilting of the country to assist in the production of over-deepened basins In all probability two or more of the agencies have assisted in the production of the lakes The same causes have probably operated in the production of the lakes of other Alpine regions It is now very definitely assumed by many geologists that such lakes as Lucerne, Thun, and Geneva, and the Italian Alpine lakes, are partly due to movements which affected valleys which had been formed by ordinary frost and river erosion in pre-glacial times The uplifting of an outer zone caused a damming back of the river drainage, and unless the river erosion could keep pace with the rate of uplift a series of lakes would obviously result The extension of the glaciers, the production of great moraines and the erosive action of the ice sheets have given to these lakes many of their modern characteristics, though originally their origin was tectonic, following on river erosion The question is by no means settled yet, however

The Great Lakes of the St Lawrence — The five great lakes of the St Lawrence constitute the largest fresh-water system in the world, and are obviously of tremendous importance in the physical and economic geography of North America The question of their

origin is as difficult as that of the Alpine lakes just mentioned, and geologists are by no means agreed It is usually regarded as quite certain that the lakes were not in existence in pre-glacial times, and that during and since the glacial period three causes have been at work (1) Changes in level of the earth's crust, of a local and uneven character, (2) some amount of glacial erosion, and (3) damming up of drainage by deposits formed across pre-existing valleys The relative value of each of these agencies is obviously difficult or impossible of determination, and it is more than probable that the effectiveness of these causes has been different in the different lakes of this important system There is again much difference of opinion as to the value to be attached to ice-erosion, some think it the most important of all, while others would regard it as only of secondary importance

Very similar considerations probably apply to the North European system of fresh-water lakes It may, however, be pointed out, that a pronounced line or belt of depression extends from the Norway Deep across Sweden, the Gulf of Finland and the Great Lakes to the White Sea The student should study a good orographical map of Northern Europe to appreciate the significance of this remarkable belt of depression Lakes Wener, Wetter, and Malar in Scandinavia, a deeper part of the Northern Baltic, the Gulf of Finland, Lakes Ladoga and Onega in Russia, and the White Sea are apparently parts of this great curved belt of depression

Salt Lakes —Lakes continually lose water by evaporation and seepage This loss is made good by inflowing rivers If the supply of water from rivers is more than sufficient to make good the loss, there is an outflowing river or rivers, and the dissolved salts in the water of the lake are approximately the same in kind and in

quantity as in the water of the inflowing rivers. The quantity of salts is too small appreciably to affect the taste and the lake is said to be a "fresh-water lake." If the supply of water is insufficient to maintain an outflow the proportion of dissolved salts must clearly increase as the inflowing water is evaporated, and the lake is a "salt-lake." This concentration of salts continues to saturation point—which is often reached first in some shallow gulf or bay of the lake—and precipitation of some of the salts occurs (*see* Chapter XI., Salts in the Rocks, p. 220). Salt lakes occur in all the continents in regions where the rainfall is scanty, the atmosphere usually very dry, and evaporation proportionately rapid. The regions where they occur are frequently known as regions of closed or internal drainage.

Lakes are transitory Features of the Earth's Surface.—Judged by geological standards, lakes cannot be very long-lived features as a rule. Two processes are often at work shortening their existence as lakes. The first is the cutting down of the barrier by the outflow, a process which will obviously in course of time lower the level of the lake until the complete cutting through of the dam may eventually drain off the whole lake. The other process is that of deposition, the filling up of the lake with deposits brought from the higher reaches of the rivers which feed the lake. This latter process is obvious and well known. Many concrete examples can readily be given. Three well-known ones must suffice. Lakes Derwentwater and Bassenthwaite are obviously part of a former great continuous sheet of fresh water, but the rivers Greta from the east and Newlands Beck from the west have brought down alluvium until they have formed the large flat to the west of Keswick which now separates the two lakes.

An exactly similar process has divided lakes Brienz and Thun in the valley of the Aar in Switzerland A side tributary from the Bernese Oberland has pushed its delta completely across the valley, thus making two lakes where formerly there was one continuous sheet of water

The silting up of Lake Geneva by the Rhone is a very well-known example The great river comes through its transverse gorge turbid with glacial mud and other river-borne materials which it deposits in the upper end of Lake Geneva In this way some square miles of deltaic deposit have been formed since Roman times Near the town of Geneva there may be seen the difference between two rivers originally charged with glacial mud, one of which has dropped its suspended material while passing through a lake, and the other has not The Arve flows as a turbid stream laden with so much fine clay that a cement works has been set up to utilise it, the Rhone is a clear stream The waters of the two streams mingle but slowly, and the remarkable difference between them may be seen for a considerable distance

Unless some change in conditions is set up within the immediate geological future, Lake Geneva, and many another Swiss lake, will cease to exist In its place there will be a flat, alluvial land, and such are quite common in all mountain regions where lakes occur The present lakes *seem* only a small part of the lake systems which existed at the close of the last glacial period

Vanished Lakes of different types are common in many parts In the Pennine valleys are traces of many shallow lakes or meres, some of which have been completely drained in comparatively recent times Professor P F Kendall has shown that a series of lakes existed in the northern valleys of the North York moors

in glacial times, and he has reproduced some of their outlines with considerable care Greater lakes are known to have existed in recent times in different parts of the continents Lake Bonneville is the name given to a lake which existed in the great basin of North America in comparatively recent times Great Salt Lake is a comparatively small descendant of this lake, whose terrace deposits are found at a height of about 1000 feet above the present lake level A vast lake which existed in the prairie region of Central North America has been named Lake Agassiz

Uses of Lakes —One of the first and most interesting parts played by lakes in the economy of nature is that of control of the flow of rivers Floods are checked by the lakes through which so many mountain streams flow Especially does this apply to numerous rivers which derive their supply from the snows and glaciers of mountains Lake Constance minimises the floods of the Rhine, the lakes of Central Switzerland control the floods of the Aar tributaries, and Lake Geneva equalises the flow of the Rhone So obvious is this control of flooded rivers that the course of the Aar below the confluence of the Saane and near where it makes its great bend to the north-eastward, has been altered so that the river now flows into Lake Bienne, and thus the dangerous floods which were formerly characteristic of the Bernese Aar are now prevented Exactly the same is seen in the case of the lakes of Scotland and the Lake District, the mountain streams are often flooded to a disastrous extent, but the rise of the rivers in flood time is far less than it would be if the flood water had not been spread over the greater surface of the lake or lakes Since reservoirs have been constructed near the source of so many of the Pennine streams it has been noticed that disastrous floods are

not nearly so numerous as they were formerly Artificial lakes are playing the same part as the natural lakes of other regions

Lakes, both natural and artificial, are used for supplying towns with water Loch Katrine supplies Glasgow, and Thirlmere, in the Lake District, supplies Manchester When the Lancashire city took over Thirlmere for a water supply, the natural dam was raised and the depth and volume of the lake considerably increased The scenery of the district does not seem to have suffered materially in consequence of these changes Crummock Water has been raised to increase its volume by the towns of Cockermouth and Workington, and the old footpath on the southern side of the lake is now submerged for the most part It is interesting to note what a large number of artificial lakes or reservoirs are to be seen in that part of the Southern Pennines between the Craven gap and the Peak of Derbyshire The prevalent rock is millstone grit, which holds large quantities of soft water, the rainfall is considerable, and the immense population of the neighbouring East Lancashire and West Riding manufacturing districts demands the storage of large quantities of water

It is scarcely necessary to insist that lakes appeal to man from a scenic point of view The mountain lakes, of deep, clear water, lying among the majestic hills and often surrounded by forests, offer irresistible charms to the residents in the busy regions of the world, and the lands of mountain lakes are among the most highly favoured holiday regions The lakes of the English Lake District, the wilder lakes of the Scottish Highlands, the lakes of the Alps, especially those on the Italian side, need only be mentioned

It may also be pointed out that lakes have great direct economic value The waters of mountain lakes

supply energy which is now used in many ways in Norway and Sweden, in Switzerland and in North America The great lakes of North America are also of great importance in providing a means of access for shipping into the middle of a wealthy continent

Lakes and Climate—Lakes exert some influence on the climate of surrounding lands The water of the lakes cools the air in summer and warms it in winter, except when the lake is frozen over The climate of Scotland and Scandinavia among European lands must be affected by the great expanse of water in the very numerous lakes, the humidity of the air is increased, and the range of temperature reduced Large lakes will exert a still greater influence The Great Lakes of North America must give to the air an enormous quantity of vapour and so affect the atmosphere considerably It is due to the influence of the lakes that fruit-growing is such an important industry in the two great peninsulas—Ontario, between Lakes Ontario, Erie, and Huron, and Michigan, between Lakes Huron and Michigan

The mild climate of the shores of Lake Constance, and the climate of Montreux, Vevey, and Lausanne on Lake Geneva are well known, and are sufficient testimony to the ameliorating effect of the Swiss lakes The delightful climate of some of the upper Alpine valleys on the Italian side, and the growth of the olive there, are in some measure, if only slightly, due to the deep Italian lakes.

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Note (*a*) Sir John Murray classified lakes as follows in the *Ency Brit*, 11th edition, vol xvi

A Rock Basins B Barrier Basins some of the barriers being the following—landslips, glaciers, lateral moraines frontal moraines, irregular glacial drifts sand dunes, river alluvium, lava flows C Organic Basins, including Tundra lakes and some coral reef lakes

Note (*b*) The following particulars of some lakes may be useful

(1) Maximum depth of some British lakes in feet Morar 1017, Ness 754, Lomond 623, Tay 508 Wastwater 258, Lower Erne 226, Windermere 219, Ullswater 205, Mask 191, Llydau 190, Coniston 184, Corrib 152, Ennerdale 148, Crummock 144, Neagh 102 Derwentwater 72, Bassenthwaite 70

(2) Maximum depth of some European lakes in feet Mjosen 1483, Como 1345, Maggiore 1220, Garda 1124 Geneva 1015, Ochrida 942, Constance 827 Onega 740, Ladoga 732, Wetter 413, Wener 292

(3) Depth of some other lakes Asia—Baikal 5413, Aral 222 Africa—Nyasa 2580, Tanganyika 2100 North America—Superior 1008, Erie 210 South America—Titicaca 924 New Zealand—Manapouri 1458, Taupo 534

Note (*c*) The salt content of some famous lakes in grams per litre, is as follows Dead Sea 237, Great Salt Lake 221, the open Caspian Sea 13, the partly cut-off Karabugas, maximum salt content 285, Aral Sea 11, Lake Van 19 The general average of sea-water is about 35

CHAPTER IX

LAND-FORMS COAST-LINES AND INLETS OF THE SEA

COAST-LINES are of varied character, and as the type of coast possessed by a region is of first-rate importance in connection with its development and its trading possibilities, it is necessary to study them briefly At the first glance coast types might seem to be too numerous and too varied for systematic classification, and as a matter of fact there is as yet no complete and inclusive scheme We may, however, briefly indicate some points of geographical interest, and outline briefly some tentative methods of classification which have been widely adopted

Concordant and Discordant Coasts.—Some coast-lines extend for long distances parallel to the strike of well-defined mountain ranges They follow the *grain* of the country Such coasts have been termed *concordant*, the name being self-explanatory. Other coasts cut across the grain of the rocks of the region, these are described as *discordant* coasts Some examples will make this clearer The Pyrenees form a well-defined Alpine mountain chain, with the grain of the folded rocks running on the whole from east to west The Cantabrians continue this structure into the north-west of Spain The deep inlet of the Bay of Biscay extends into the angle between the mountainous coast of the north of Spain and the low coast of south-western

France The southern shore of the Bay of Biscay is concordant towards the Cantabrians, it runs almost strictly parallel to the grain of the folded mountains The bathymetric lines (that is, contour lines showing depths of sea-floor) of the Bay of Biscay on its southern side also run broadly parallel to the mountains, thus making the concordance more pronounced At the western end the varied and broken coast of Galicia cuts across the grain of the rocks just as plainly as a transverse section of a long beam cuts across the grain of the wood This western coast is discordant It seems reasonable to suppose that the folded mountains once extended farther to the west When the last phases of the foundering of the North Atlantic took place the fracture cut off the mountains sharply at their western end Similarly, the Atlas mountains end off sharply at the western end The northern, or Maritime Atlas, ends off abruptly in the Riff coast, the Great Atlas in the rocky coast of Cape Ghir, in both cases the grain of the rocks being cut transversely The Great Atlas may have been cut off at the same time and in the same way as the Cantabrian mountains The Canary Islands are mountain fragments, parts of that Atlas which once continued well out into what is now the North Atlantic Ocean From Tangier to south of Cape Ghir is a typical discordant coast, the coast parallel to the Northern Atlas is a concordant one

Most of the Pacific coast of both the Americas is concordant, the fold-mountains running parallel in a general way to the coast-line There are obviously portions where, probably owing to subsidences, the coast becomes locally discordant, the northern end of Puget Sound, and the southern end of the peninsula of Lower California, will readily occur to the student as examples

The eastern coast of the Persian Gulf, the eastern

coast of the Bay of Bengal, and the coast of Kamchatka are other examples of coasts where fold-mountains run parallel in general to the coast-line

We have hitherto regarded coasts chiefly in relation to folded mountains of Alpine type We may, however, consider some of those regions where the folds have not produced mountains in the usual sense, but where the grain of the country (the strike of the rocks) is the same over a considerable area The coast of Sussex is parallel to the general direction of the South Downs from east of Selsey to near Beachy Head, this is a concordant coast The English coast of the narrow seas from Beachy Head to the North Foreland evidently cuts across the grain of the country, it is a good example of a discordant coast The corresponding coast of France is similarly discordant

The Yorkshire coast from Bridlington to the mouth of the Tees is discordant, as it cuts across the grain of the Jurassic and Cretaceous rocks The varied features of the coast depend upon the presence of a succession of hard and soft rocks cut across by the sea The hard rocks stand out as headlands, the bays occur where softer rocks have been exposed to the action of the sea

Discordant coasts show greater variety of structure than concordant coasts Different types of rocks are met with in rapid succession and thus give rise to varied features A discordant coast is usually rich in capes and openings, and very often rocky cliffs alternate with stretches of low flat beaches

Neutral Coasts.—It is often the case that the rocks of a maritime region are practically horizontal, either level-bedded sediments or igneous rocks which have an even, horizontal extension The coastal outline cannot be said to be parallel or oblique to the direction of the rocks or to the grain of the country The

direction or orientation of the coast is independent of the internal structure of the rocks Such a coast, which cannot be described as either concordant or discordant, is a *neutral coast* Where the plain of Northern China meets the China Sea is a typical example The Tundra coasts of the Arctic regions are also typically neutral

The coasts of the great European plain have been described as doubly neutral, there is an outer neutral coast and an inner coast behind the lagoons or wadden Other examples, such as the Landes coast of the Bay of Biscay, will occur to the student

Pacific and Atlantic Coasts—The late Professor Suess of Vienna called attention to the remarkable difference between the coasts of the Pacific and those of the Atlantic The great Pacific Ocean is largely bordered by long lines of young fold-mountains which run concordantly with the coast The whole of the west coast of the Americas, with the exception of part of Mexico, has these long lines of mountains close to the sea The continental shelf is narrow, or, in other words, the deep ocean comes very close to the coast-line The same holds on the western side of the Pacific, only we must look for the real ocean boundary on the outer side of the long festoon-lines of volcanic islands and peninsulas mentioned in Chapters II and IV

Within the long system of islands lie inland seas, and behind these is the complex coastal system of continental Asia itself, a coast sometimes concordant, sometimes discordant, and sometimes neutral Asia has thus a sort of double coast There is a very similar system of double coasts in the West Indies and Central America

The coasts of the Atlantic are quite different, scarcely anywhere is the outline parallel to long lines of fold-mountains Slight exceptions, such as the north of Spain and possibly the north of the Gulf of Guinea, scarcely

count in the vast extent of coast under consideration The western coast of Norway is not of the Pacific type, as the grain of the old Caledonian Alps does not extend along the axis of Scandinavia, but has a direction more nearly north-east and south-west. Neither are the coasts of New England and Nova Scotia strictly concordant The Atlantic coasts are extremely irregular In one part Alpine mountains are broken off sharply against comparatively deep sea, we have already seen examples on the north-west of Spain and in the north-western corner of Africa In another place a plateau ends off sharply with a fractured edge Such is the west coast of the Spanish Meseta, part of the west coast of Africa, and a good deal of the east of South America, in these cases the coastal plain is narrow and there is a very narrow submarine continental shelf In yet other regions low plains, with low flat coasts, pass gradually into shallow seas where the continental shelf is obviously of great extent The coasts of the south of the North Sea, the western coast of France, the south-eastern coast of the United States, and the coasts of Argentina are obviously of this type Most of these are neutral coasts, as already pointed out The distinguishing character of the Atlantic is this irregularity, contrasted with the regular type which holds for so much of the Pacific

The Indian Ocean is bounded by varied coast-lines of Atlantic type, that is, discordant and neutral coasts, both on the African and Australian sides, and in most of Southern Asia The only exceptions are the Pacific types of the Persian Gulf and the possibly modified-Pacific coast of Burma and the Malay Peninsula

The Pacific coast of America has islands running chiefly in long lines parallel to the general coastal trend Note, for example, the islands off the coast of

British Columbia and those off Southern Chile. On the western side the long festoons of Eastern Asia and Malaysia show to some extent the same linear arrangement. The islands of the Atlantic are irregular, detached continental masses; Newfoundland is part of eastern North America with its grain abruptly cut off, indicating a former extension into the North Atlantic. The British Islands are a part of north-western Europe, quite recently detached from the continent by the discordant breach of the Strait of Dover and the English Channel. The Canary Islands are fragments of the Great Atlas, where the latter extends out into the Atlantic almost at right angles to the general north and south direction of the ocean.

The Atlantic, with its variety of coast-line, has a varied hinterland, which on the whole is much more readily approachable than the immediate hinterland of the Pacific. The great wall of the western mountains and the plateaux of the Americas must always prove serious barriers to communication between the ocean and the immense continental plains. As with eastern North America so with Europe, the varied and frequently discordant coast offers many avenues of access to the continental interior. This is not without its bearing upon the advanced state of civilisation of these continents, and especially important in its bearing upon those possibilities of interchange of commodities which play so important a part in modern life. The disturbances on the western Pacific margin in recent geological times which have depressed the long mountain lines, so that many of their higher parts stand up as islands from a comparatively deep sea, have provided openings from the ocean to eastern Asia which make it more favourably situated for trade than western America.

Other shorter Pacific coasts show some of the same principles Persia is shut off from the Persian Gulf and the Arabian Sea by the Alpine wall of the Zagros mountains, passes through which are difficult Persia must wait for the advent of Alpine tunnelling on a considerable scale before its oases and river valleys are brought fully into touch with the outer world on the oceanic side Burma is accessible from that stretch of discordant coast which runs athwart the direction of the Irrawadi and Salwen rivers Communication across the mountain wall running parallel to the eastern coast of the Bay of Bengal is difficult, and access to the interior is now provided by railways which run parallel to the fold-mountains and not across them

It should be pointed out here, however, that discordant and neutral coasts are not always conducive to ready approach to continents Plateaux frequently end off abruptly, the ocean on their margins having apparently foundered Eastern South America has much in common with parts of western Africa, and it is believed that the South Atlantic is a foundered portion of the crust which formerly existed as a land connection So also Eastern Africa, the Deccan, and the plateau of Western Australia are so much alike that geologists believe them to be portions of a continent of the Mesozoic era, to which Professor Suess gave the name Gondwanaland (*see* Chapter IV , p 76) The coasts of these broken plateau-systems are notoriously difficult, and the coastal plains are narrow , rivers usually descend from the plateau in waterfalls which impede navigation, and generally such a plateau-continent is by no means easy of access Eastern South America is fortunate in possessing the great basin of the Amazon between the plateau of the north-east and the East-Brazilian plateau Here the coast-line and the structure of the land is of the same

type as the Mississippi Basin, only on a larger scale, and the continent thus possesses a region to which Africa offers no real counterpart

The Continental Shelf.—Where the sea meets the present land-boundary is seldom the real outer edge of a continent, the latter frequently extends as a submarine platform for some distance out to sea, then there is a comparatively rapid descent to real oceanic depths of from 10,000 to 15,000 feet The shallow submarine continuation of the continent is known as the continental shelf

Concordant coasts have usually a narrow belt of continental shelf, discordant coasts vary considerably, but neutral coasts almost invariably have wide continental shelves The existence of a wide shelf is of very great importance On it most of the continental debris brought down by rivers is deposited Here there is abundance of food for marine life, crustacea, mollusca, and fishes are plentiful The food supply of a maritime region is thus largely influenced by the nature and extent of the continental shelf, which in its turn is intimately connected with the type of coast-line

Coastal Openings —There is no complete classification which includes all inlets into the land Even the common names—sea, gulf, bay—are used in varying senses One only needs to compare the White Sea, the Baltic Sea, the North Sea, and the Black Sea to realise in what various senses the name *sea* is used

The partially enclosed seas of Central America furnish another example, we speak of the Caribbean Sea and the Gulf of Mexico, but the Mediterranean Seas concerned are of one type It is sometimes understood that a *gulf* has a fairly narrow opening, and this holds for such well-known examples as the Persian Gulf, the Gulf of Mexico, the Gulf of Pechili But we also speak

of the Gulf of Guinea, the great "bight" of Western Africa. The name bay is also used for very different types of openings, compare Hudson Bay with the Bay of Bengal Baffin's Bay is a curious example of the use of the word bay for a sea passage which was probably at first thought to be a bay. The Gulf of Aden and the Gulf of Oman are funnel-shaped seas leading through straits to inland seas, one of which is called a gulf, the other a sea It is obvious that the whole nomenclature is full of anomalies

The great Inland Seas—The most famous of these are the European Seas, the Southern Group and the Northern Group The Mediterranean Sea is the largest inland sea in the world, with a length of 2000 miles and an area of a million square miles, or eight times the area of the British Isles It is divisible into well-defined eastern and western parts separated by the shallow Sicilian ridge The Eastern Mediterranean descends to a depth of over 14,000 feet, the greatest depths being near the unstable regions connected with the fold-mountain system of Southern Europe Crete and Cyprus are the higher parts of submerged mountain ranges The Adriatic Sea is a depressed crust block between the Apennines and the Dinaric Alps The eastern coast of the Adriatic is of a type almost unique, the Dalmatian type The Western Mediterranean is divided by the Sardinian-Corsican horst, which separates the Tyrrhenian deep from the Ligurian Sea

The Mediterranean shows examples of the three leading types of coast-lines From the Riff Coast of Morocco to Cape Bon is concordant, as are also the southern coast of Asia Minor, the western Adriatic, and the coast of Spain from Gibraltar to Cape de Gata The north-eastern coast of Spain is clearly discordant,

as is the southern coast of Greece where the mountain upfolds form the promontories of the famous Morea The west coast of Asia Minor is a heterogeneous coast mainly of discordant type Neutral coasts are not so well represented in the Mediterranean, but the Northern Adriatic, the Carcassonne coast of France, and the Orán coasts are examples

The Black Sea is a deep gulf of the Mediterranean, approached through the narrow straits, the Dardanelles and Bosphorus It has a maximum depth of 8600 feet, and is being filled up with relative rapidity by the numerous rivers which enter it It is not so salty as the Mediterranean, its water containing about sixteen parts of dissolved salts per thousand against thirty-seven parts per thousand in the Mediterranean A strong current flows from the Black Sea to the Mediterranean during most of the year

The Northern Group of European Seas includes the Baltic, the North Sea, the narrow seas on the south and west of England, and the White Sea These are all shallow seas The North Sea and at least the *Southern* Baltic are parts of the Great European Plain depressed only very slightly below sea-level The English Channel and the Dover Strait are also very shallow, almost all of it being less than 300 feet deep, that is, far less than the elevation of the North Downs, the South Downs, and the Forest Hills in the middle of the Weald The shallowness of these seas, the great amount of continental debris brought into them and spread over their floors, and the moderately low temperature, make them amongst the most famous fishing grounds in the world All the countries round the North Sea derive important food supplies from the fisheries of that sea

The Asiatic Inner Seas.—From the Bay of Bengal

all round the east of Asia runs a great series of mountain loops, many parts of which are depressed below sea-level, the summits only appearing as islands Outside these curves of volcanic islands are the greatest oceanic depths yet known Inside the curves are the submerged parts of the continent, forming the inner seas These, while by no means shallow, are not nearly so deep as the great ocean outside The seas thus partly enclosed between the outer primary coast of Asia and the inner secondary coast, are the Sea of Okhotsk, Japan Sea, Yellow Sea, East China Sea, and the South China Sea The Yellow Sea is shallower than the others, probably because it has been filled up with so much continental debris from the easily-weathered loess lands of the interior The Great Chinese rivers, Hoang-ho and Yang-tse, and the lesser Pei-ho bring down immense quantities of yellow loam which is deposited between the inner and outer coasts of the continent

The Inland Seas of Central America—These seas, like those of Eastern Asia, lie between an inner and outer coast The primary or outer coast extends from the Bahamas through the Lesser Antilles to the Coast Range of Venezuela This is a modified concordant coast, with, of course, many breaches due to sinking of the land and the penetration of the Atlantic Outside this primary coast is the deepest known part of the Atlantic, another point of analogy with the Asiatic island-loops and inner seas Between the outer line of islands and the inner coasts of the continent are the three sunken basins, the Gulf of Mexico, the Bartlett Basin, and the Caribbean Sea The greatest depth in these Mediterranean seas is 20,560 feet, compared with 31,366 feet in the Atlantic immediately outside the curve of volcanic islands

Hudson Bay—Hudson Bay corresponds to the shallow northern inland seas of Europe Its average depth is about 400 feet, and its greatest known depth 660 feet Like its European counterparts, it receives considerable continental drainage, and its floor must be covered with great deposits of continental debris brought down by the numerous rivers which empty their waters into it

Valley Openings into the Seas

Rias, Fiords, Fiards—There are some types of openings into the coasts to which definite, fairly consistent names are applied, and the names of which connote certain clear ideas of structure and mode of origin

Rias—These are sunken, somewhat shallow, V-shaped valleys, as a rule they gradually become shallower and narrower as they are followed inland, and they end in gradually shelving shores, such that the slope of the valley inland is a continuation of the submarine slope of the opening Rivers usually enter the bay at the upper end, but the width and depth of the valley frequently seem out of proportion to the size of the stream The typical rias are the openings on the discordant coast of the north-west corner of Spain They were studied and systematically described by von Richthofen, who gave the precise connotation to the name Typical rias are generally found on discordant coasts where the full force of the tides is felt, and it is difficult to resist the conclusion that the waves have had a considerable share in forming this particular type of opening, if not by marine denudation, at least by maintaining them open through sweeping out deposits which would otherwise fill them up

The openings of the west of Brittany are also rias,

and excellent examples are furnished by the series of openings in Kerry, south-west Ireland Other examples are found in southern China, on the Maine Coast in the U S A , in North Island, New Zealand, where Auckland Harbour is a typical ria, and in such openings as Plymouth Sound and Falmouth Harbour

Fiords.—These are long, narrow openings, with steep walls, extending into the land for long distances, and often branching in a remarkable manner They are very deep and often much deeper far inland than at the mouth ; in fact, a great number of fiords seem to have some kind of submarine bar at the mouth, either of rock or of morainic deposits

Fiords are found in high latitudes, in countries now heavily glaciated or which were obviously glaciated in the Pleistocene Ice Age , hence many writers have held that they are valleys which have been formed mainly by glacial erosion, obviously aided by river erosion These openings occur in fractured tablelands or on coasts where there has been much disturbance during recent geological times Where the faults have been carefully mapped it has been found that the fracture lines coincide to a surprising degree with the direction of the principal and branch fiords It seems, therefore, that the fiords were probably determined in the first place by faults River valleys developed along the shatter-belts of the fault lines, and these were cut deeply before glacial times Glaciers probably once filled many of these deep-cut valleys, and their gouging and planing actions have possibly worn out some of the deeper parts, rounded off some of the sides, and especially glaciated the rocks at the entrances Afterwards, in comparatively recent times, subsidence has caused the sea to fill the valleys, thus producing the present features It would thus seem that subsidence,

[By courtesy of the High Commissioner for New Zealand

PLATE XIV.—A FIORD IN NEW ZEALAND. "MILFORD SOUND," NEW ZEALAND

PLATE XV—THE BOCCHE DI CATTARO, THE FAMOUS COMPLEX OPENING IN THE "BLACK MOUNTAINS"

A series of transverse and longitudinal depressions give the opening its striking features

Rugged Limestone Mountains in the foreground

fracturing, river, ice, and sea action have probably all played a part in the production of fiords.

The typical fiords are those of the Norwegian coast, where Sogne Fiord, one of the best-known, extends inland for over 100 miles, and has an average width of only three miles. Most of the openings on the west of Scotland and the north-west of Ireland are fiords. Across the North Atlantic, on the coasts of Iceland, Greenland (both east and west), and Labrador there are typical fiords. Fine examples occur on the west side of North America, in British Columbia and Alaska, and also in the extreme south-west of South America. Finally, on the west coast of South Island, New Zealand, there are fiords as grand as those of Norway.

It will be noticed that fiords occur both in the younger Alpine mountain lands, such as British Columbia and in Southern Chile and the New Zealand Alps, and in fractured and much worn plateaux of ancient rock like those of Labrador, Scotland, and Western Norway.

Fiards.—These are in a sense intermediate in structure between fiords and rias. They occur on lower coasts than fiords, and their sides are not so high and steep; otherwise they have much of the fiord character. The openings on the south-east coast of Sweden are the types of fiards.

Föhrden.—These are long, narrow, and much branched openings which penetrate eastern Jutland and the Baltic coasts of Schleswig-Holstein. The coast is a low flat one, and though these inlets have sometimes been called fiords, there is no real likeness to the deep, steep sided openings of the true fiord character.

Lagoons or shallow coastal Lakes.—Limans are lakes formed behind the outermost deposits of deltas, where a part of the estuary has been cut off by the

advancing deposit of river alluvium. Between the delta of the Danube and that of the Don there are numerous shallow lakes of this type, which are only accessible with difficulty from the Black Sea. Liman coasts are most readily developed in enclosed, tideless seas, though the *etangs* of the Landes of the Bay of Biscay are somewhat of the same nature. These shallow lakelets of the Landes coast communicate with each other by channels roughly parallel to the coast, thus forming a sort of chain of lagoons. These latter are somewhat similar to the *wadden* which are found behind the sand dunes of the low coast of the Netherlands (*see* Chapter VI.) **Haffs** are the brackish-water estuarine lakes found at the mouths of some of the Baltic rivers and shut off from the sea by the long spits of sand (chiefly blown sand) called *nehrungs*. Like other lagoon-like formations on a low coast these are very shallow, being rarely more than 30 feet in depth.

Fohrden, limans, etangs, wadden, and haffs are thus all lagoon formations existing on or immediately behind, low flat coasts. They are obviously due to the action of rivers in bringing down alluvium, to winds in blowing sand into dunes along the coast, or to a combination of these.

The Dalmatian Coast.—A coast of almost unique character occurs in the eastern Adriatic. From north-east of Trieste to the mountains of Montenegro the Mesozoic rocks are thrown into a series of folds with their long extensions roughly parallel to the coast. On the seaward side there has been considerable subsidence and some fracture, and the sea penetrates the folded land of the Dinaric Alps, many transverse gaps allowing the sea to extend inland, and to penetrate longitudinally the synclinal folds of the Karst country

The transverse channels and longitudinal depressions isolate a great number of islands which have their general orientation parallel to the Adriatic extension Other transverse openings and longitudinal troughs form the complex systems of *valloni* for which the region is famous The best known of these rock-bound openings is the Bocche di Cattaro in the Montenegrin mountains, where three submerged longitudinal valleys are connected by transverse openings This opening has often been described as a fiord, but that name should not be applied to it It has little of the true fiord character

Coasts modified by Animal or Plant Growth.—On many tropical and sub-tropical coasts the action of organisms plays an important part in the structure of the coast-line, and in its defence against marine erosion Coral reefs and mangrove swamps are the most important of these coastal growths

Coral Reefs.—Corals are animals of simple organisation belonging to the class Cœlenterata Many of them secrete Calcium Carbonate from the sea water, and form a strong cylindrical or cup-shaped structure with radiating, strong divisions Some are simple, others are compound, and a number of corals form a colony The reef-building corals accumulate, by their continued branching and budding, large masses of solid limestone, which grow outwards and upwards, always, of course within the sea The building up of the enormous masses of limestone found on many coasts and in some parts of the open ocean, is no doubt assisted by the work of algæ which also secrete and deposit calcareous matter Reef-building corals inhabit shallow sea water in warm seas, hence their operations are confined to the seas of tropical and sub-tropical regions The seas in which these reef-builders flourish must be normally salt and

almost free from sediment, hence coral reefs do not accumulate opposite the mouths of rivers

So far as coastal formations are concerned, there are two not very sharply divided types of coral reefs, those which are very close to the coast, called fringing reefs, and those which are some distance away, called barrier reefs

In many tropical seas the protective effect of coral reefs on the coast must be very great, the outside of the reef receives the full force of the attack of the waves, the water inside the reef is usually still Ordinary marine coast-erosion must be practically non-existent on these coasts It is obvious that the existence of a belt of calm water between the inner coast and the barrier reef will often prove of great importance in shipping Ships often find shelter inside the barrier reef when violent storms are lashing the sea into fury outside

It was pointed out above that reef-building corals only exist in warm seas to-day, and their resultant masses of limestone are only found in these warmer seas, but in Mesozoic times corals of reef-building type existed in temperate regions also These coral-walls protect small islands and coasts from destruction by the waves, and probably their protective action must have been very important in Mesozoic times

The great Australian Barrier Reef—This is the greatest reef in the world; it extends along the north-eastern coast of Australia for a distance of 1200 miles, and has a width of from 10 to 90 miles There are openings through it, opposite to the mouths of rivers which bring down mud and sand from the continent The coral polyps do not flourish in muddy water, hence there are gaps where the land-debris is borne athwart the line of the reef

Mangrove Swamps—These occur on some low-lying tropical coasts There are several species of those peculiar trees which have earned for their forests the name mangrove They grow best between tidal limits in the equatorial rainy region, where there are alternations of heavy rains and scorching sunshine The trees send out their bent roots into the reeking, tropical slime The fruit falling into the water sends up another shoot, and so the tangled mass grows The waves and currents of the ocean are checked by this tangle of roots and low gnarled stems, and any drifted sediment is thus arrested Decayed vegetation continually adds to the accumulation, producing the characteristic unhealthy and uninhabited mangrove swamp, with its stinking mire from which gases ascend, and through which crustacea crawl and in which mollusca embed themselves The inner true land coast is thus protected by the mangrove forest, which tends to push itself outwards into the quieter areas of tropical seas

Instability of Coasts—Coast-lines are very unstable features Marine erosion is for ever at work, undercutting cliffs, cutting caves, making blow holes, separating masses of rock from the mainland, and thus forming the "stacks" which are so prominent along many coasts The destruction of cliffs is aided by the action of rain and frost Cliffs of soft rocks such as sand and clay are rapidly destroyed, as may be seen on the Holderness coast of Yorkshire and the coast of Norfolk The cliffs of boulder clay to the north of Blackpool have been cut away with great rapidity within the last hundred years Even hard rocks are worn away by the ceaseless attack, especially in directions where the prevalent winds blow the waves with great violence against the land The work is done first of all by the mechanical action of the waves themselves, these are driven with great force

against the rocks, and their impact is so strong that large masses of rock are often dislodged In rocks where there is much jointing the mechanical action of the waves is supplemented by the work done by compressed air; the advancing waves drive the air forward into these joints, and the alternate compression and expansion of the air assists in the erosion of the cliffs Further, the waves hurl detached pieces of rock against the cliffs, thus using as tools the material which they have dislodged from the shore or which has beeen brought down by rivers

The results of erosion vary with the kind of rock, the degree of exposure to waves and currents, and the time during which the rocks have been exposed to the forces at work Professor W M Davis's "structure, process, stage" is well illustrated by the results of marine erosion.

The coasts of Britain are so obviously being worn away, somewhat rapidly on certain parts of the coast, that there was at one time considerable alarm, and a Royal Commission was appointed to investigate the subject It was established that the loss which is apparent in certain parts of the coast is at least compensated by the deposition of sediment elsewhere, and that there is little or no net loss taking place at present

In Britain and in many other maritime regions, when a limited locality is considered, the loss is not only quite apparent, but is often obviously taking place at a great rate One of the best known examples is the Island of Heligoland, near the mouth of the Elbe. The island is at present a mere relic of what it was a thousand years ago

Reconstruction on Coasts—On many low coasts reconstruction or growth is in progress In some cases it is mainly due to the action of the wind which blows

PLATE XVI.—DISSECTED COAST IN CORNWALL SHOWING EROSION

[By courtesy of J. Ranson, Esq., F.G.S.

PLATE XVII.—A SUBMERGED FOREST AT LEASOWE, IN CHESHIRE.

the sand slightly farther inland from tidal beaches Accumulations thus take place along the coast and the lands gain on the sea In other cases the tides or other currents set in a definite direction and thus sweep along material which has been set free by coast erosion else-

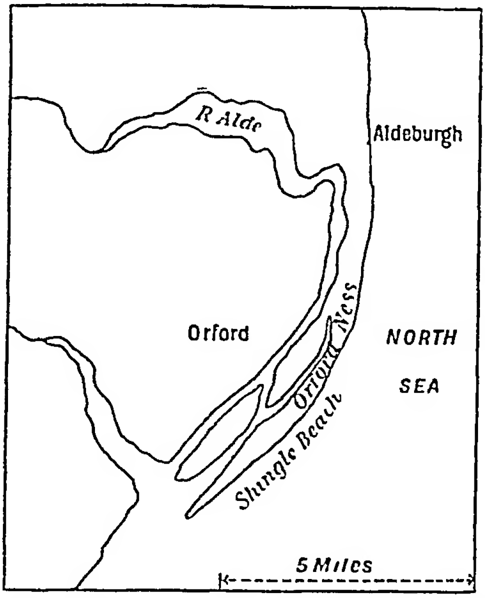

FIG 18.—THE DEFLECTION OF THE RIVER ALDE, IN SUFFOLK, BY THE TIDE DRIFTED MATERIAL FROM THE NORTH A LONG SHINGLE BEACH HAS BEEN FORMED, INSIDE WHICH THE RIVER ALDE NOW FLOWS ROUGHLY PARALLEL TO THE NORTH SEA COAST

where or brought down by river from the land Spurn Head in south-east Yorkshire is a low sandy spit which has grown considerably, largely at the expense of the disappearing Holderness coast farther north, aided by the alluvium brought down by the Humber It has already been mentioned that in the east of Norfolk

there has been accumulated the drifted material from the north, and that in this way the estuaries of the sluggish Norfolk rivers have been converted into shallow lakes. Somewhat farther south is the interesting case of the river Alde, which now enters the sea much to the south of its former estuary. In the thirteenth century the river flowed past Aldeburgh. Now a long spit of land has grown to the south and the river flows parallel to the shore for quite a long distance.

River drift is brought down and distributed along shore-lines or deposited in the estuaries and bays, or deltas are pushed out into the sea. The rivers of Westmorland and north Lancashire carry down enormous quantities of eroded material into Morecambe Bay, and in the upper part of that bay are large areas of newly-formed land. The rock-debris brought down by the Ribble and the Mersey is distributed along the shore between the two estuaries, and the land at Southport and Formby is slowly gaining seawards. Especially in non-tidal seas like the Mediterranean and Black Sea, rivers are gradually adding to their deltas and pushing them farther into the sea. The student may well read Sir Charles Lyell's classic accounts of the deltas of the Mississippi and the Ganges; the growth of river deposits and how they are pushing outwards the coast-line are described in the famous *Principles of Geology*, with all Lyell's usual clearness.

Changes of Coast-lines due to Changes of Level.—This subject was necessarily referred to in Chapter IV. It may be again mentioned with special references to coastal changes. If we confine ourselves to the historic period, it is surprising how many changes of level on coast-lines have now been recorded, sometimes a rising of the land, sometimes a sinking, at least *relatively* rising and sinking. The Mediterranean coasts

abound with examples The pillars of the famous temple of Serapis near Naples show a record of alternate rising and falling of the coast in that region The coasts of Sicily, of Southern Greece, of the Islands of the Ægean, of the west of Asia Minor, almost everywhere show signs of changes of level In the Island of Crete some old docks are now about 30 feet above sea-level A classic example of these coastal changes is the coast of Sweden, also referred to in Chapter IV This coast was studied by Celsius and Linnæus Depression as well as elevation are there in progress

Another now famous region is Alaska There was a great earthquake in 1899, and considerable changes in the coast were afterwards noticed In Yakutat Bay, Messrs Tarr and Martin recorded an uplift in one part of as much as 47 feet There was depression in some parts of the neighbouring region

Other disturbed regions where changes of coast level have been actually noticed are—the West Indies, Japan, and the north-west coast of India

If we extend the review over the whole of the Pleistocene period, or even the time since the passing of the last phase of the glacial period, we see that coastal changes have been both great and widespread The commonest evidence of elevation consists of raised beaches, and these are quite common on many coasts They are of frequent occurrence on the coasts of Britain, and may be especially well studied on the Scottish coasts On most of the north-eastern coast of Ireland there are raised beaches showing uplift of from 8 to 20 feet In the plain of Limavady evidence of coastal elevation may be plainly seen Raised beaches in the north of Norway indicate an elevation of many hundreds of feet within the recent period In north eastern North America evidence

of elevation is seen in the neighbourhood of Boston, where uplift of only a few feet has occurred, and in Labrador, where the elevation has probably been hundreds of feet On the other hand, depression of coast lands will obviously not be so easy to trace Submerged forests or roots of trees below tide level are satisfactory evidence of such depression, and these are by no means uncommon There are many, again, on different parts of the British coasts In the North of Ireland there are, to the west of Portrush, remains of a forest which are exposed at low tide Evidently there has been depression of the coast-line at that point Two miles away, on the eastern side of Portrush, are raised beaches and sea caves now some distance inland, showing that on a neighbouring part of the same coast there has been recent elevation

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This monumental work, translated into English and published in four volumes, is a storehouse of information and suggestion, on crustal movements, earth-forms, etc

The reader may well turn, in addition to the above, to Sir C LYELL's *Principles of Geology* The last edition (2 vols) may be borrowed from many libraries The work is now out of print

CHAPTER X

OCEANOGRAPHY, OR THE GEOGRAPHY OF THE SEAS

THE merest glance at an equal area map of the world, or at a globe, makes one realise how much greater is the area of the earth's solid crust which is covered by water than that which is not so covered, the surface of the sea is far greater than that of the land

The area of the earth's surface is 197,000,000 square miles, of this about 142,000,000 square miles are sea and 55,000,000 square miles are land—that is, 72 per cent sea and 28 per cent land respectively, the surface of the sea is to that of the land approximately as 5 2 If the volume of the sea below sea-level is compared with that of the land above sea-level the disparity is seen to be still greater Reckoning from the common datum, the greatest known depth of the sea is not very much more than the greatest known height of land, the deepest ocean sounding is 32,089 feet, the top of Mount Everest is 29,002 feet [1] above sea-level But the *average depth* of the ocean is estimated to be about 12,500 feet, while the *average height* of the land is estimated at 2250 feet A simple calculation will show

[1] This is the height according to Indian Government Survey, the average of most recent surveys is 29,141 feet.

that the volumes are nearly in the ratio of 14 5 1 This difference in volume is of more than mere academic interest to man, it means that the influence of this immense body of water, with its peculiar values of specific heat and latent heat, is very great and that many of the phenomena which take place on the earth's surface are largely dependent upon the sea

It is necessary to distinguish the different oceanic depths—which seem, on the whole, to be so well marked that they are in all probability consequent upon some fundamental processes which have influenced the form of the earth's "crust"

The Continental Shelf—Surrounding many parts of the continents there is a gradually shelving sea-floor which passes by a low gradient, often of not more than 1°, from sea-level at the shore line to about 100 fathoms This is the continental shelf, and it is an important feature because on it most of the erosion waste from the land is deposited, in its waters waves due to winds and tides are best developed, and marine life to serve as food for man is most prolific The continental shelf occupies about 8 per cent of the oceanic area

The origin of the continental shelf has given rise to much discussion and three methods of formation have been advanced, these are —(1) deposition of eroded land waste and the gradual smoothing out of the piled-up material, (2) the cutting back of the sea and the consequent recession inland of the shore line, (3) raising of the sea-level or depression of the land, making the continental shelf to be a drowned lowland plain It is doubtful if many cases can be explained by one only of the above processes, and it seems highly probable that a combination of two or three would be necessary to account for most of the continental shelves which can be studied Whatever their origin, it may be

claimed with some confidence that the existing continental shelves are not of any great geological age

The Continental Edge and the Continental Slope — At the outer edge of the Continental Shelf is the Continental Edge, beyond which begins the Continental Slope On the latter the gradient is steeper than on the continental shelf The continental slope may be defined as that part which is between 600 feet and 6000 feet Beyond this comes the deep Oceanic Plain, from 6000 to 18,000 feet deep, occupying 55 to 60 per cent of the whole oceanic area

The **Oceanic Plain**, or Abyssal Plain, is of remarkable evenness of surface, a fact which has been observed frequently in the laying of submarine telegraph cables The *Britannic* found in the North Atlantic a great area with no gradient which would have been apparent to the naked eye, while Agassiz found a submarine plain on the floor of the Pacific which was 3200 miles across, and showed no greater slope than 9 inches to the mile, or 1 in 7040

Oceanic Deeps —Here and there in the oceanic floor are more or less extensive "deeps"—that is, hollows in the usually even plain, these vary from 18,000 feet to over 30,000 feet in depth Sir John Murray enumerated fifty-seven such deeps The Tuscarora Deep, in the North Pacific, not far from Japan, is the most extensive deep yet known, another famous one is the Aldrich Deep in the South Pacific, which has given several soundings of over 30,000 feet The deepest Pacific sounding is 32,089 feet, the deepest Atlantic sounding is given as 31,366 feet

The Oceans

It is customary to speak of five oceans—Pacific, Atlantic, Indian, Arctic and Antarctic, but it is

obvious that they are all continuous, especially is it difficult to delimit the Antarctic from the Atlantic, Indian and Pacific oceans

The **Pacific** is by far the greatest of the oceans, its area being about 64,000,000 square miles—that is, 9,000,000 square miles more than the total land surface of the earth Its average depth is probably slightly over $2\frac{1}{2}$ miles, the western half being distinctly deeper than the eastern half Many of its great deeps lie quite near the lines of fold mountains which almost surround it (p 70) In the western half are many groups of volcanic and coral islands, most of which appear to rise from submarine plateaux, these submarine plateaux alternate with numerous deeps which often show soundings of more than 24,000 feet The continental islands, Japan, New Guinea and New Zealand, appear to be parts of a "chain" of partially submerged volcanic lands, with fold mountains of Alpine type, and they are probably parts of the real continental border of the Pacific on the western side See Fig 92

The **Atlantic** is the second in area of the great oceans, covering about 31,500,000 square miles—that is, almost half the area of the Pacific (see Fig 80) It is not so deep as the latter ocean, its average depth being estimated at about 2 miles Its structure is quite different from that of the Pacific, for a long ridge rises from its floor, runs almost midway between its two margins, and thus divides it into two basins This ridge is known as the Challenger Ridge in the South Atlantic and the Dolphin Ridge in the North Atlantic, it is almost discontinuous at the equator At the northern end it widens out into the submarine platform which stretches from the British Isles to Greenland, this plateau is known as the Telegraph Plateau, because it was on it that the first cables were laid North of this feature

and lying almost at right angles to the trend of the mid-Atlantic rise is a well-marked ridge extending from the British Isles to Iceland and Greenland, this is known as the Scoto-Icelandic divide, and an important part of it is known as the Wyville-Thompson Ridge The depth over this narrow ridge is only about 1200 feet

The **Indian Ocean**, like the Atlantic and the Pacific, is freely open to the Antarctic Ocean, but it does not extend far into the Northern Hemisphere (*see* Figs 22 and 23) This ocean is fairly uniform in depth, about 70 per cent of it being over 12,000 feet, with a few deeps of over 18,000 feet in the eastern half In the western half are a number of patches less than 6000 feet deep from which rise groups of islands Connected with these are the continental islands of Madagascar and Ceylon, the whole probably forming the edge of an old continental region

The **Arctic Ocean** lies to the north of Eurasia and North America, these continents present wide continental shelves towards the North Polar Basin, which is the deepest part of it The connection with the Pacific through Bering Strait is both narrow and very shallow, with the North Atlantic it connects by water of about 2500 feet deep The maximum depth is 13,200 feet, and it is estimated that its volume is not more than $\frac{1}{10}$th of that of the Atlantic Ocean

The **Antarctic Ocean** forms the oceanic girdle of the southern lands It is obvious that there can be no natural limit to it northwards, so the latitude line 60° S is generally selected as an arbitrary boundary This is a relatively shallow ocean and vast areas of it are between 6000 and 12,000 feet deep There is a shallow connector between Graham Land and Cape Horn, and another between the Antarctic Continent and Australia South

of Africa, in latitude 60°–65° S, there is a deep of over 18,000 feet, the extent of which is not yet well known

Salts in Sea Water

The most familiar property of sea water is its salinity or saltiness, which is evidenced at once by its taste Sea water is salty everywhere but not to the same extent All rivers carry what is known as fresh water to the sea, and it is clear that locally, at any rate, the composition of sea water must be affected by the nature and the volume of the river water which enters it at different places Rain water contains no salts at all, hence the surface water of the sea in regions of heavy rainfall must be less salty than the surface water in regions of low rainfall and great evaporation Further, the ice of icebergs and icefloes contains very little salt, therefore the melting of these must add considerable quantities of fresh water to the surface of the sea in those regions where much ice is melted

The variation of saltiness in the great open oceans is far less than the variation in enclosed seas, but as the volume of the latter is only a small fraction of that of the oceans as a whole, it will be clear that the variations in composition in the enclosed seas will make but little difference in the *average* saltiness of sea water The salts in sea water amount to 35 parts per 1000 on an average, and the salinity of nearly all the surface water of the great oceans varies only between the limits of 33 and 37 parts per thousand (written 33°/₀₀ and 37°/₀₀) The exceptions occur mainly in narrow belts round the coasts of the continents

The "salts" usually assumed to be present in sea water must exist largely as ions rather than as separate salts, hence it is better to represent the average salinity

by giving the amount of the principal positive and negative ions present in parts per 1000

	Parts per 1000 (°/₀₀)
Sodium (Na)	10 722
Magnesium (Mg)	1 316
Calcium (Ca)	0 420
Potassium (K)	0 382
Chlorine (Cl)	19 324
Sulphate (SO_4)	2 696
Carbonate (CO_3)	0 074
Bromine (Br)	0 066
	35 000°/₀₀

The *relative* proportion of these ions or of dissolved salts remains practically the same everywhere in spite of variations in total salinity

In such partially enclosed seas as the Mediterranean, the Red Sea and the Persian Gulf, which are in the sub-tropical high-pressure belt, and into which a relatively small quantity of river water is carried, the salinity is high, in the Persian Gulf it is said to vary between 37 and 38°/₀₀, in the Mediterranean between 37 and 39°/₀₀, and in the Red Sea between 37 and 41°/₀₀ On the other hand, it is easy to understand that partly enclosed seas in the cool temperate low-pressure belt, into which vast quantities of river water may be poured and where evaporation is not very great, will be less salty than the open ocean, the salinity of the Sea of Okhotsk varies from 30 to 32°/₀₀, that of the North Sea from 31 to 35°/₀₀, while the Baltic shows variations from 3 to 15°/₀₀

The Temperature of the Sea

In discussing the temperature of sea water two considerations have to be taken into account—variations at the surface and variations with depth The recorded readings at the surface of the open ocean have varied between 26° F and 90° F, but in the Persian Gulf and the Red Sea readings of 94° F and 96° F have been taken Broadly speaking, the surface temperature diminishes from the equator to the poles, but there are many irregularities, due chiefly to prevalent winds, ocean currents and the nearness of great land masses

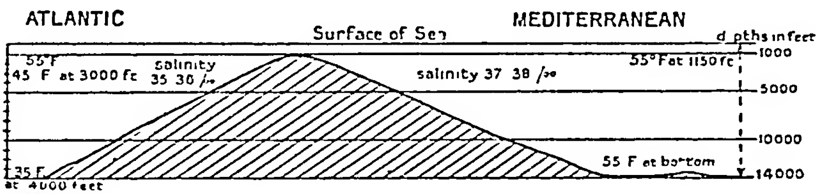

Fig 19 —A Diagrammatic Vertical Section of the Sea and the Bar at the Entrance to the Mediterranean

(Vertical scale greatly exaggerated)

Much of the open ocean in the neighbourhood of the equator has an average surface temperature of about 79° F, with an annual range of less than 10° F, and a daily range of 1°–2° F The Caribbean Sea, the Gulf of Mexico and the Mediterranean are warmer than the open Atlantic in corresponding latitudes, the Baltic Sea and Hudson Bay are colder than the Atlantic

The variation with depth is not so easily stated Even in the open ocean seasonal surface temperatures may differ by as much as 30° F, but at a depth of 600 feet there is no evidence of any seasonal variation whatever At such depths the temperature at any one spot is constant From this depth down to about

3600 feet there is a rapid fall of temperature, followed by a more gradual fall to about 12,000 feet, below which the whole of the deep ocean seems to be uniformly cold with a temperature of about 34°–36° F.

There are other interesting modifications in partially enclosed seas, especially those which have a submarine bar at their entrance; two well-known cases are mentioned as examples. The Mediterranean has a submarine bar at the entrance 1150 feet below the surface, and the temperature of that enclosed sea corresponds approximately to that of the Atlantic down to that depth. Below 1150 feet the temperature of the Mediterranean remains practically constant at 55° F., down to its greatest depth of 14,400 feet; the temperature of the Atlantic, following the law for the open ocean, continues to fall, and at a depth of 14,400 feet has gone down to 35° F. Similarly the entrance to the Red Sea at the Strait of Bab el Mandeb is partially barred by a submarine ridge 1200 feet below the surface. Below this depth down to the bottom at 7200 feet the Red Sea has a temperature of 70° F.

The Density of Sea Water

Sea water varies in density according to its salinity, its temperature, and in a less degree according to the pressure to which it is subjected. These variations are of importance in connection with problems of the circulation of sea water. In discussions of density of sea water comparisons are made either with pure water at its temperature of maximum density, 39.2° F., or with water at 60° F., as a standard.

The average density of sea water at the surface is 1.025; sea water containing 40 °/₀₀ of dissolved salts has a density of 1.030. Water is compressed by $\frac{1}{20\,000}$ of its volume by an increase of pressure of one atmosphere;

at a depth of 24,000 feet, where the pressure is 720 atmospheres, the compression will be approximately $\frac{1}{28}$ of the volume at the surface In discussions of density at or near the surface the latter factor may obviously be left out of account, and the points to be considered are the amount of dissolved salts and the temperature

One more point of contrast between sea water and fresh water may be mentioned here Pure water freezes at 32° F, and its temperature of maximum density is 39 2° F Sea water of average composition—that is, containing 35°/₀₀ of dissolved salts, freezes at 28° F, which is also its temperature of maximum density

The Circulation of Sea Water

Various factors cause circulatory movements in the mobile waters of the sea, the chief of which are (1) the rotation of the earth, (2) the action of the winds, (3) differences of density, due to changes of temperature or of salinity Of the circulatory movements thus set up we may distinguish (*a*) local currents of exchange of warm and cold water, or highly saline with less saline water, (*b*) definite, well-marked currents in the open ocean, moving with considerable velocity, (*c*) general surface drifts of much lower velocity affecting mainly the surface waters over a wide area These various circulations will be studied by considering concrete examples to which some general principles are applied

Local Currents of Exchange.—It has already been pointed out that the water of the Mediterranean Sea is, on the whole, more salty than that of the adjacent Atlantic, the salinity of the western basin is mostly between 37°/₀₀ and 38°/₀₀ The rainfall is light, relatively few big rivers pour their "fresh water" into the sea, and there is much evaporation Hence the level of the Mediterranean tends to fall and a surface current of

less salty water flows through the Strait of Gibraltar into the great midland sea This current is strengthened when the Atlantic tidal wave reaches the Bay of Gibraltar, but it is not dependent on the tide as is shown by the fact that the current still flows into the Mediterranean when the Atlantic tidal wave is ebbing from the Strait There is a return current of denser and more saline water which flows outwards underneath the inward current, but it is very much less in volume

Another well-known current flows from the Black Sea through the Sea of Marmora, and below it there is a return current of denser and salter water entering the Black Sea , the volume of the latter has been estimated as about $\frac{1}{3000}$ of that of the surface current

Similar local currents will readily occur to the reader, such as, among others, the current of normal oceanic water from the Indian Ocean into the hot and salty Red Sea There is strong current of brackish water from the cool Baltic into the more normally saline North Sea

Ocean Currents —These are of a different order from the local currents which have been described above They are often well-marked, clear currents in the ocean, their waters different in temperature and salinity from the surrounding seas " There is a river in the ocean " was written of the best known of them by an enthusiastic writer in the middle of the nineteenth century There has been much discussion as to their cause , differences in temperature and salinity, the rotation of the earth, and the effects of the winds have all been invoked There can be little doubt that all these play their part, but it is now generally agreed that the main cause must be sought in the steady trade winds which blow over so much of the tropical and sub-tropical oceans, and in the effects of the rotation of the earth

The probable relative values to be given to the different factors may appear clearer when the actual currents of the great oceans are carefully considered

The Currents of the Atlantic Ocean—The south-east trade wind drives before it a well-marked South Equatorial Current which flows westward until it reaches the bulging eastern angle of Brazil, here it is divided into two branches, the northern one of which flows parallel to the Guiana coast, enters the Caribbean Sea, and helps to form the Gulf Stream The southern branch goes southward, more or less parallel to the coast of Southern Brazil, as the Brazil Current This branch continues until it comes under the influence of the westerly winds of the South Atlantic, here it turns eastward, as a less well-defined current, until its waters merge with the cool Benguela Current The latter current flows northward along the west coast of Africa, where its cool waters have marked climatic effects The rotatory circulation of the South Atlantic is completed when the water of the Benguela Current, now warmed, joins the South Equatorial Current

Corresponding to the South Equatorial Current is the North Equatorial Current, which is driven westward by the north-east trade winds On reaching the Windward Islands of the West Indies part of it passes into the Caribbean Sea and part flows away northward The warm surface water of the Caribbean Sea is driven forward into the Gulf of Mexico, where it tends to raise the level of that partially enclosed sea, the warmed, salty water is forced through the narrow Florida Strait as the famous Gulf Stream, the best known of all ocean currents This current is over 300 feet deep, and its surface waters as it leaves the narrow strait have a temperature of 79°–80° F, it has at first a velocity of 4 to 5 miles an hour, and its waters are readily distin-

guishable from those of the neighbouring seas. This remarkable current flows parallel to the North American coast, widens out gradually and becomes shallower, its waters become cooler and less salty, until in about

FIG. 20.—OCEANIC CIRCULATION OF THE ATLANTIC OCEAN

"Warm" currents are shown by continuous lines; "Cold" currents by broken lines. The strength and constancy of the currents are broadly indicated by the thickness of the lines.

(Map drawn on the Sanson Flamsteed Equal Area Projection.)

40°–41° N., and especially when it meets the cold Labrador Current, it turns off more to the east and gradually ceases to be a well-defined current in mid-Atlantic. Its waters now merge in the widespread

surface drift of the North Atlantic, which is driven north-eastward by the frequent south-westerly winds of that region This surface drift cannot be described as a current in the true sense, as its waters are not clearly different from those of the surrounding seas to the extent characteristic of well-defined ocean currents The surface waters move at very variable rates at different times and in different localities, but the average velocity is little more than 5 miles a day

This surface drift gradually changes in direction and in distribution, a part of it continuing past the British Isles, over the Scoto-Icelandic Rise and along the Norwegian coast, the other part curves round the high-pressure region of the North Atlantic to become the Canaries Current of the sub-tropical North Atlantic This finally joins the North Equatorial Current and the circulation is completed as in the South Atlantic

To replace the water which is carried northward by the Gulf Stream and the North Atlantic Drift there are cold currents coming from the Arctic Ocean into the Atlantic The best known is the Labrador Current, which brings cold water and many icebergs from Baffin's Bay and Davis Strait past the eastern shores of North America into comparatively low latitudes, the other is the East Greenland Current, whose cold waters, mingled with those of the Labrador Current, seem to pass gradually under the North Atlantic Drift There is an analogous cold current in the south-west of the South Atlantic which bears the appropriate name of the Falkland Current and which helps to give to the Falkland Islands a climate in many respects similar to that of Newfoundland

Finally, it must be noted that between the North and South Equatorial Currents flowing westward there is a distinct current of warm water flowing eastward,

this is the Equatorial Counter Current, it has been suggested that this is part of the water from the westward driven currents "reflected" from the South American land angle already mentioned, but this explanation does not seem altogether satisfactory This current is more in evidence in the Gulf of Guinea than near the American coast, and the convergence of the North Equatorial and South Equatorial Currents may help to form this swirl of surface water in the opposite direction

The Currents of the Pacific Ocean—This ocean is much bigger than the Atlantic and its shape is different The Atlantic is somewhat like a long S-shaped lane with roughly parallel sides, the Pacific is a vast spherical triangle with its base on the Southern Ocean and its apex at the narrow and shallow Bering Strait Hence, though the origin and general character of the currents are much the same, they are not so well-marked as in the Atlantic There is a rotatory circulation in the North Pacific which corresponds to that in the North Atlantic The North Equatorial Current in the Pacific is more interrupted by island groups, the Kuro Shiwo or Japanese Current is not so pronounced as the Gulf Stream though it occupies a similar place, and the North Pacific Drift does not seem to have such marked effects as that of the North Atlantic The entry from the Arctic Ocean is narrow and shallow in the case of the Pacific, wide in the case of the Atlantic, hence the cold Kamchatka Current, though similar in general relationships, is not so powerful as the cold Labrador Current of the Atlantic. The currents in the South Pacific may be followed on the diagram-map (Fig 21), and the general correspondence with the Atlantic currents will be readily seen

The Currents of the Indian Ocean.—In this ocean it is

only the southern system which is fairly complete, the northern system is mainly cut out by the great Asiatic continent The general circulation is like that of the South Atlantic and there will be no difficulty in

FIG 21 —OCEANIC CIRCULATION OF THE PACIFIC OCEAN

"Warm" currents are shown by continuous lines, "Cold" currents by broken lines

(Map drawn on Mollweide's Homolographic Projection, with 160° W as the central meridian, the equatorial distance from E to W of the map is a semi circumference of the globe)

following the various currents and in appreciating the similarity In the Indian Ocean, north of the equator, there is a North Equatorial Current which normally would be expected to flow westward, and between this

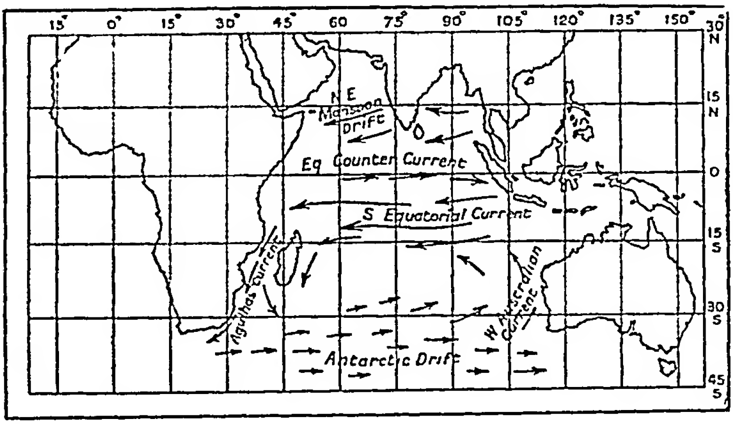

FIG 22.—OCEANIC CIRCULATION OF THE INDIAN OCEAN—JANUARY.

(Drawn on Gall's Projection.)

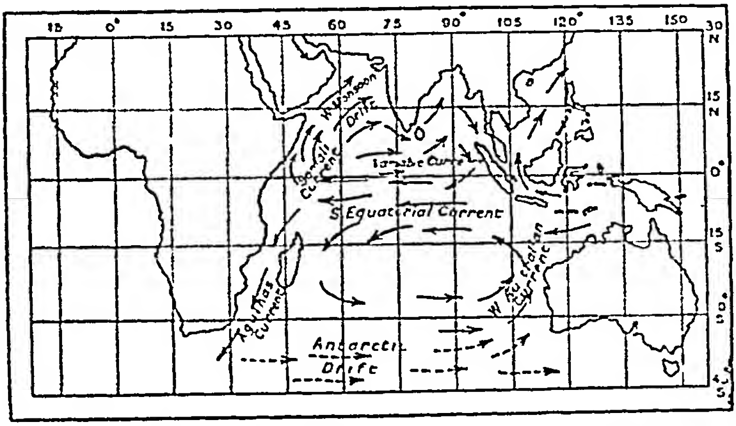

FIG 23.—OCEANIC CIRCULATION OF THE INDIAN OCEAN—JULY.

(Drawn on Gall's Projection.)

and the South Equatorial Current there is seen for part of the year the normal counter-current as in the other equatorial oceans It is of great interest to learn that in late "summer" both these currents are completely cut out by a monsoon-driven current flowing from west to east The bearing of this remarkable seasonal change on the theory of the origin of ocean currents is obvious

General Widespread "Drifts"

It has already been noticed that in the North Atlantic there is a surface drift of warm water, fed by the warm Gulf Stream and driven by the prevalent south-westerly winds, and there is a similar drift, though not so pronounced, in the North Pacific No doubt the earth's rotation has something to do with the origin of both these "drifts" and the currents from which they are fed, but it is generally believed that the winds are the more important cause In the great Southern Ocean there is little interference by land masses and the westerly winds blow steadily all the year round, further, they are more directly from the west than in the Northern hemisphere There is therefore a general surface drift—known as the Antarctic Drift—which is remarkably steady in its eastward direction The surface water is cold and of less than normal salinity (33 5–$34^{\circ}/_{\circ\circ}$ of salts as a rule), and the cold eastward drift is able to supply some of the cold water of the Peru, the Benguela and the West Australian currents, which play such an important part in the circulation of the three great oceans

Tides in the Oceans and Seas

Among the most familiar phenomena to dwellers on the edge of the seas are the tides The water rises and falls, comes in and retires some distance, or flows and ebbs, as we say, roughly twice in the course of a day

More accurately the average time between successive tides is 12 hours 25 minutes, or for the two tides of the day, 24 hours 50 minutes

Ordinary observation teaches much about the tides but a complete explanation of all that happens is not yet available There are no tides, or only very slight ones, in inland seas, thus in the Mediterranean it reaches only 2 to 3 feet The highest tides are experienced in partially enclosed shallow seas and ria-like estuaries

That the tides are in some way connected with the moon is obvious to the most casual observer, and the time interval mentioned above has to do with the rotation of the earth and the revolution of the moon round the earth The earth rotates once in 24 hours and the moon revolves in 28 days, therefore, to bring a point on the earth's surface directly under the moon again after one rotation, the time required will be 24 hours plus $\frac{1}{28}$ of 24 hours, which works out to 24 hours 50 minutes, approximately, and thus corresponds with the observed average time

It is well known also that the tides vary in height during a lunar month A few days after the new moon and the full moon the tides are higher than usual, these are the *Spring Tides*, for a few days after the first and third quarters of the moon the rise and fall of the tide are less than usual, these are the *Neap Tides* There is no absolute quantitative law connecting these two, but, speaking generally, the range of the spring tides is from two to three times as great as that of the neap tides

There is also a half-yearly variation in the tides Soon after the spring and autumn equinoxes the spring tides are a little higher than usual These unusually high tides are known as the *Equinoctial Spring Tides*

The Cause of the Tides—To understand the cause of

the tides more clearly it will help if we imagine the earth as a rigid globe surrounded by a homogeneous ocean The moon is distant from the globe by about 240,000 miles Now the attraction of gravity is directly proportional to the mass and inversely proportional to the square of the distance The water on that side of the earth which is nearest the moon is approximately 4000 miles nearer the moon than is the centre of the earth, which we may regard as the centre of mass of the globe There will thus be a difference in the moon's attraction for the covering of water as compared with the solid globe, and the water "under the moon" will rise or bulge upwards So also on the farther side of the earth from the moon, the solid earth is nearer the moon and is attracted more than the water, and there is a relative rise or bulge of the homogeneous ocean on the other side

The above explanation does not show why there are spring and neap tides at fortnightly intervals, to account for these the differential attraction of the sun must be added to that of the moon The sun is immensely greater than the moon, but it is about 330 times farther away from the earth and its tide-producing force is therefore less The tide-making value of the moon is to that of the sun as 9 4, or, as given by Supan, 57 26 Now, at new moon the sun and the moon are on the same side of the earth and not very far from being in a straight line with it, hence their tide-producing forces must be added At full moon the sun and moon are on opposite sides of the earth and again the tide-making effects are to be added When the moon is at first and third quarters the direction of the sun from the earth is at right angles to that of the moon, and it will be clear that the tide-producing effects must now neutralise each other to some extent If the sun

had as much influence as the moon there would be no tides at all, but, as pointed out above, that of the moon is greater than that of the sun as 9 : 4, or as 57 : 26 These values must now be subtracted, and the low neap tides are thus explained There will obviously be two

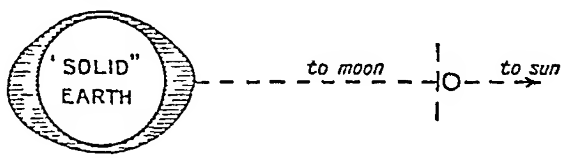

FIG 24 —TIDE AS PRODUCED BY THE SUN AND MOON ACTING TOGETHER (AT NEW MOON)

The effects of the two are *added* *Spring Tides* result

spring tides and two neap tides in a lunar month, and in the limit cases the range of the former would be to that of the latter as $9+4 : 9-4$, or about 2·6 times as great This theoretical value corresponds approximately

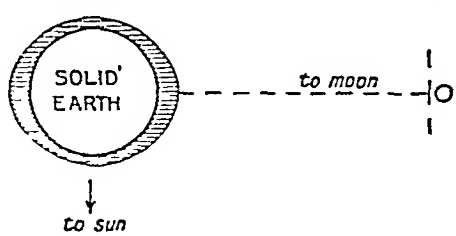

FIG 25 —TIDE AS PRODUCED BY SUN AND MOON, WHEN THE LATTER IS IN QUADRATURE

The effects of the two are *subtracted* *Neap Tides* result

with the observed value mentioned in the earlier part of the section

The ideal condition of the tides described above is, of course, not realised on the earth's surface with its irregular distribution of land and water The theoretical

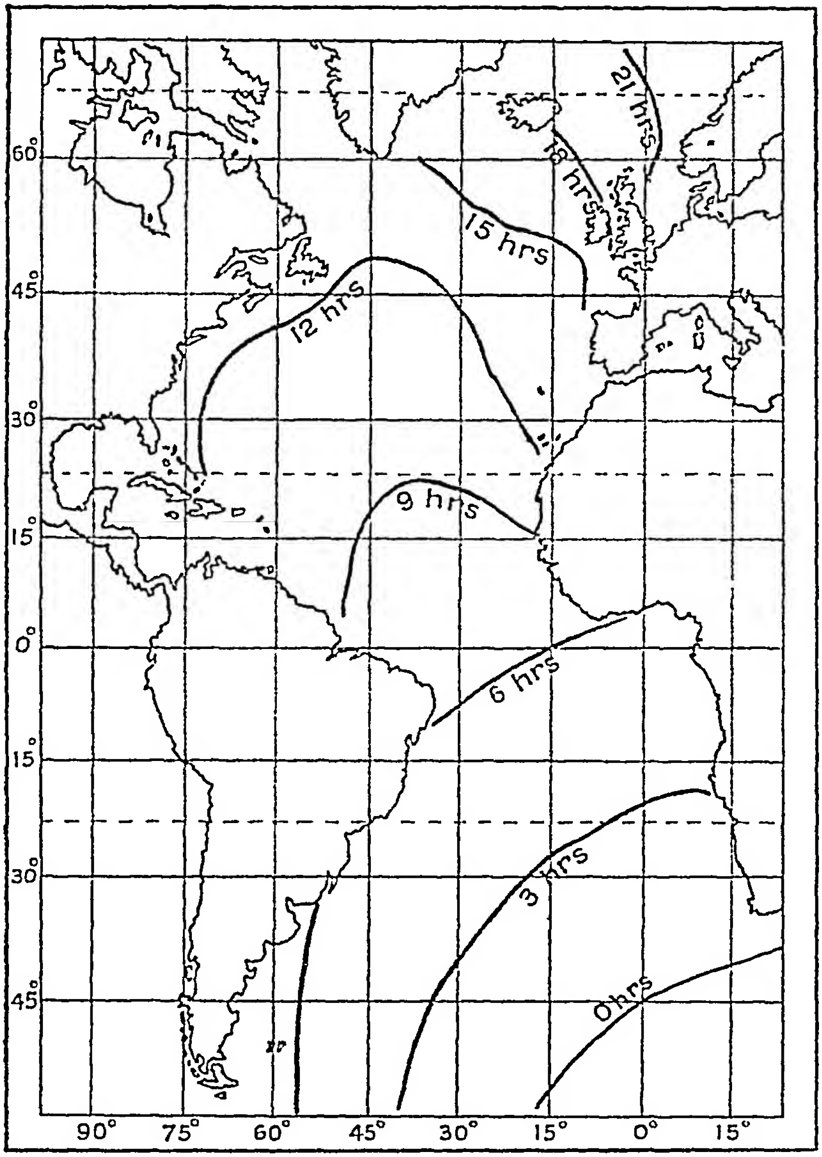

FIG 26—CO TIDAL LINES OF THE ATLANTIC OCEAN

Showing the advance of the tidal wave from the Great Southern Ocean,—somewhat generalised (after the late Sir George Airy, once Astronomer Royal)

(Drawn on Gall's Stereographic Cylindrical Projection)

tidal waves, with their crests and troughs 12 hours 25 minutes apart in time, cannot travel round the world, except in the Southern Ocean, because the continents stand athwart their course as barriers There seems little doubt that independent tidal waves originate in the three great oceans—the Pacific, the Atlantic and the Indian, but the actual resultant wave that we know seems to be the one that develops in the South Pacific and Antarctic oceans, that is, in the greatest expanse of oceanic waters, and this wave absorbs the others This great tidal wave from the Southern oceans enters the Atlantic between Africa and South America as a lateral wave and moves along the ocean from south to north as along a wide, deep and winding canal, overwhelming and absorbing the Atlantic's own tidal wave

The tide in the mid-Atlantic causes a rise and fall of a little over 2 feet, as is shown on tide gauges on oceanic islands, but as the wave motion comes to the wide continental shelf there is much interference by friction against the shallow floor, the downward movement of the water particles is partly suppressed and the upper part of the wave moves forward and piles up into a higher wave In shallow seas and more especially in funnel-shaped estuaries, such as *rias*, the piling up process produces a bore or eagre Examples are well known from the Severn, the Humber, the Bay of Fundy, the Yang-tse-Kiang and many other estuaries

The Atlantic tidal wave approaches the British Isles from the south-west and divides into "branches," one of which travels up the English Channel and the other round the north of Scotland These two branch waves, one of which is 12 hours behind the other, meet almost opposite the mouth of the Thames, and a reinforced tide enters the narrowing estuary of that important river

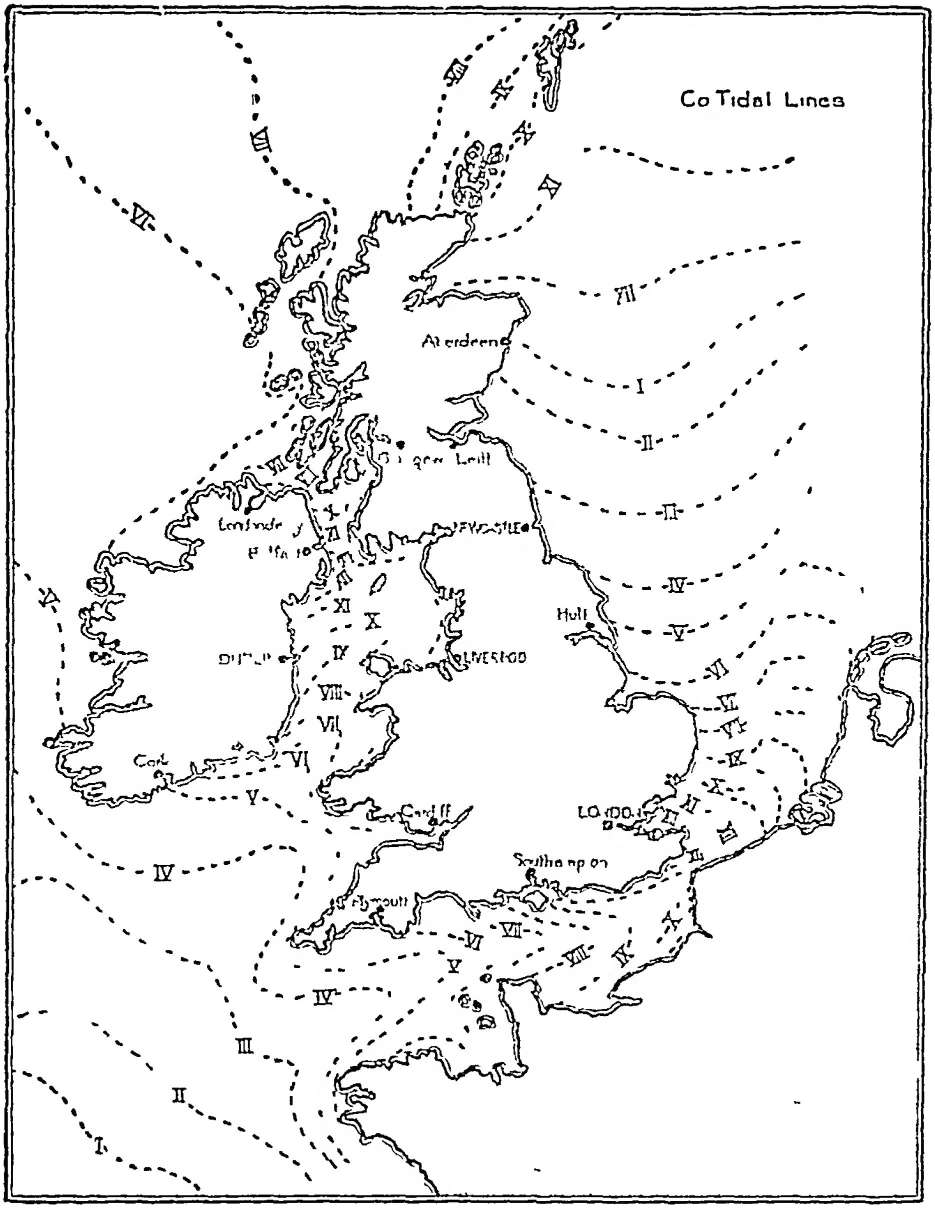

FIG 27.—DIAGRAMMATIC MAP SHOWING CO TIDAL LINES ROUND THE BRITISH ISLES

On the other hand there are places in the North Sea where one wave neutralises the other and there is little or no tidal rise and fall The study of these and other local conditions belongs to the geography of special regions In all such studies maps of co-tidal lines will be found useful, these are lines drawn through places which have high tide at the same time Examples are seen in Figs 26 and 27

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CHAPTER XI

ECONOMIC GEOGRAPHY OF THE ROCKS

MANY kinds of rocks and some of the contents of rocks are of great use to man and of considerable importance in modern life, hence the geographer should study some of the principles connected with the occurrence of those rocks and rock-contents which are of economic value

THE USES OF THE ROCKS THEMSELVES

These uses are many and varied, we shall discuss them under four heads

(*a*) Building stones
(*b*) Ornamental stones
(*c*) Paving stones and road metals
(*d*) Miscellaneous uses of some rocks

Building Stones—In the more advanced civilisations and in thickly peopled districts the use of rocks for building purposes assumes great proportions If hard, durable, and easily-worked rocks are readily obtained, it may be taken for granted that such will be used for houses, factories, and various other buildings Many different kinds of rocks are used, and it is only possible to mention some of the more important

Sandstones and Grits.—These are perhaps the most widely used of all building stones They are plentiful, widely spread, readily obtained, cut and trimmed without very much difficulty, and they are, as a rule, durable In the British Isles, sandstones from

many geological systems are used The Torridon Sandstone of the north-west of Scotland is freely used in that part of the northern Highlands where it occurs Grits of Cambrian age are used in North Wales Ordovician and Silurian grits are also used in Wales The Old Red Sandstone yields excellent building stone in the Malvern Hills and in Herefordshire Tintern Abbey and Chepstow Castle are examples of old buildings in which the rock has been used, in both cases the sandstone has suffered considerably from the long continued weathering It is also quarried in many parts of Scotland Hugh Miller, the famous Scottish stonemason geologist, worked for a long time in the sandstone quarries at Cromarty and the north side of the Moray Firth In his *My Schools and Schoolmasters* he says "Getting a suit of strong moleskin clothes, and a pair of heavy hob-nailed shoes, I only waited for the breaking up of the winter frosts to begin work in the Cromarty quarries The quarry in which I commenced my life of labour was a sandstone one, and exhibited in the section of the furze-covered bank which it presented, a bar of deep, red stone The deep, red stone formed part of an upper member of the Lower Old Red Sandstone"

The sandstones and grits of the Carboniferous system are very widely used as building stones, both the rather coarse, hard grits from the Millstone Grit formation, and the finer-grained sandstones from the Coal Measures Some of the more famous stones and localities are the Pennant Grit of the Forest of Dean, the Darley Dale sandstone of Bakewell, the sandstone of Glossop, the sandstones of Brighouse, Queensbury, and Bingley, in the West Riding, the sandstones of Rochdale, Bacup, Burnley and Nelson, the grits of the district near Colne, Bramley near Leeds, and the Craigleith Sandstone

near Edinburgh The abundance of these Carboniferous sandstones has been a great factor in the economic life of many parts of the Pennines, where the commodious stone-built houses of the working classes are well adapted to the somewhat stern climate of the hills

The New Red Sandstone (Permian and Trias) yields good building stone near Nottingham and Derby, at Mansfield, at Runcorn, and near Birkenhead, at Penrith in the Eden Valley, at Dumfries, and at Elgin in North Britain As a rule the New Red Sandstone is easily quarried and worked, but it is not so durable as the sandstones of the Carboniferous A very good example of a New Red Sandstone is Furness Abbey, near Barrow The stone, which is St Bees Sandstone from local quarries, is now very considerably weathered Sandstones newer than the Trias are not very widely used in Britain, but in other parts of the world there are many good building-stones of much newer age In the Tertiary basin of Paris there is a sandstone which has been very largely used for building, and a similar rock of Tertiary age has been used in Carolina, U S A A sandstone of recent age, formed by the consolidation of the sand of sand dunes by sea water, has been much used in Cape Town

North American Building Stones—Cambrian sandstones, from the Adirondack Hills of New York State, furnish excellent building stone, their reddish brown colour, evenness of grain, and ready accessibility have made them favourite stones for the purpose In the Atlantic coast cities, Ordovician and Silurian sandstones have been extensively used These are quarried in many parts of the Appalachian mountain system Suitable Mesozoic and even Cainozoic sandstones abound in the Western States, providing an inexhaustible supply of good building stone

Limestones—These rocks are also frequently used

for building purposes. The Oolitic limestones of the British Jurassic system furnish some of the most valuable and most famous building stones. The freestones[1] of Portland, Bath, Painswick (in the Cotswolds), Ketton, Stamford, and Ancaster are all famous examples of Oolitic limestone used for building. St Paul's Cathedral is a good example of Portland stone. Similar Oolitic limestones are worked at Caen in Normandy. Canterbury Cathedral and Westminster Abbey are built from the cream-coloured Caenstone.

The Magnesian Limestone, which occurs in the Permian system, on the eastern side of the Pennines, has been largely quarried for building purposes near Doncaster, Mansfield, and Bolsover. The Houses of Parliament in London are built chiefly of this stone from the Bolsover district. Many of the famous country seats of the Trent region are built of it, and it lasts very well in the purer air of the country. Castles built by William the Conqueror have lasted well, as has also York Minster; but the acid-tainted air of London is slowly but surely destroying it, and much of the fine chiselling of the Houses of Parliament now presents a sorry appearance. The front of the Museum of Practical Geology in Jermyn Street is Magnesian Limestone, and has stood well; it may be to some extent a case of good selection of the stone. The life of a building stone, and consequently its suitability for use, depends not only on its own nature, but on the district in which it is to be used.

A fresh-water limestone, formed of fresh-water shells and the nucules of calcareous algæ, has long been worked at Binstead in the Isle of Wight. It belongs to the Bembridge beds in the Oligocene system. Many of the older churches of Hampshire and the Isle of

[1] A freestone is one which can be worked almost equally well in all directions.

Wight are built of it, and it was long known as the Quar Abbey Stone

The nummulitic limestone of Eocene age is well known to visitors to the Great Pyramids of Egypt The disc-like forms of these large foraminiferæ are among the best-known curios of the visitor to Egypt

In Florida limestones formed of accumulations of living species of shells have been used in the construction of buildings

Slate—This member of the argillaceous group of sedimentary rocks is of considerable importance in the building industry Slates are usually found in the older systems, and in localities where much lateral pressure due to mountain-folding has taken place

Famous British localities are Llanberis and Penrhyn in the Cambrian of North Wales, Festiniog in the Ordovician of North Wales, in the Devonian rocks of Devonshire, and in the Archæan of Argyllshire The green slates of Borrowdale and other parts of the Lake District are beds of fine-grained volcanic ash which have had cleavage developed by pressure so that they split into thin regular layers

Clays and Shales—These are used for making bricks The London Clay has provided bricks for the building of a great part of London, the Gault clay of the Clay Vale, the Lias clays of the Midlands, and the Oxford Clay of Fletton, near Peterborough, are also largely used in brick-making The shales of the Coal Measures are ground by machinery into a paste, and excellent bricks are made from the "clay" thus produced Accrington, in Lancashire, and Ruabon, in North Wales, are famous for bricks made from these coal-measure shales Most of the houses in many big towns are built of bricks, the importance of clay and shale is therefore obvious

The clays which frequently occur under the coal-

seams of the Coal Measures (and which are known as "under-clays") are almost free from alkalies In consequence these clays are sufficiently infusible on heating to be made into firebricks for the linings of furnaces

Igneous Rocks —These are used for ordinary buildings only in the neighbourhood of their occurrence For example, the grey Aberdeen granite is used in Aberdeen and the immediate district Granite from various localities is imported into towns for the facing of important buildings Thus in many London streets one may see shop-fronts, banks, etc, faced with Shap granite, the large crystals of pink felspar in which rock immediately arrest the attention The pillars in front of St Pancras Station are made of this granite So also the large white crystals of felspar in the grey granite of Dartmoor may be frequently seen in London and other southern towns London Bridge is a good example Granite from Aberdeen is, of course, very frequently seen, it is especially common in many parts of the city of London Granite from the Mourne mountains may be seen in the steps of the Albert Memorial in Hyde Park A famous plutonic rock allied to granite has been imported into Britain from Laurvig on Christiana Fiord When polished its large crystals of soda-felspar impart to this rock a striking appearance This "Laurvigite" has been largely used not only in London but in many a provincial town Syenite and diorite are also frequently used Cleopatra's Needle is frequently called a syenite, it is more accurately described as a hornblende-granite The more basic rocks are less durable and very heavy, hence gabbros are not used so frequently

Rhyolites and trachytes are frequently used as building stones because they are relatively light and

durable; basalt has too splintery a fracture to be readily worked, so that its use is limited and local Basaltic columns have, however, been widely used in building piers, breakwaters, and sea-walls For example, basalt from the banks of the Rhine, showing good hexagonal columnar structure, was used in building the central sea-wall at Blackpool Many of the sea-walls and artificial levees in Holland have been largely built of the same lava columns Italian cities are largely built of tuff, that is, solidified volcanic ash

Metamorphic Rocks—Schists and gneiss are frequently used as building stones Gneiss is quite as good as granite as a rule, though it is apt to be more variable in appearance Finely laminated schists are used in many mountain regions, unless they are very fine grained they are apt to flake somewhat along the foliæ of mica, and are thus not so suitable as gneiss. The quarrymen of Switzerland call the more even grained schists "Granit," and these schists are widely used there as building stones

We have chiefly considered houses, churches, factories, public buildings, etc In addition to these we may mention docks, breakwaters, fortifications, these are often built of the harder igneous and metamorphic rocks, the hard resistant granites being the commonest of these stones

Ornamental Stones—There is no absolutely clear division between these and building stones, the stones used in facing many important buildings, and in making the pillars of banks, hotels, etc, coming partly under both heads The chief requisite for an ornamental stone is that it is capable of taking a high polish, many show in addition a beautiful play of colours In general they are obtained from the igneous and metamorphic rocks, or from sedimentary rocks which have been at least

considerably altered They are, therefore, characteristic of mountain regions Two important kinds, marble and serpentine, may be considered here

Marble.—This is a calcareous rock capable of taking a high polish The name sometimes connotes a metamorphic rock, but in trade it signifies any calcareous rock (often including even a serpentine) capable of being polished Many of the British "marbles" are simply fossiliferous limestones, in which such fossils as crinoids and corals make pleasing contrasts with the ground mass when the rock is polished A fine marble from Tiree in the Inner Hebrides is of Archæan age There is a Cambrian marble in Skye Devonian limestones from Torquay contain corals and polish well, similar rocks of Devonian age occur in the Ardennes and Eifel The infiltration of iron has sometimes produced thin red streaks, and these show up well when the rock is polished, a good example is the Devonian limestone of Plymouth There are many Carboniferous limestones which take a good polish and to which the name "marble" is then applied The red marble of Cork and the black marble of Kilkenny, the Derbyshire marble of Wirksworth, the Dent marble of the West Riding of Yorkshire, and the beautiful coral limestone of Frosterley in Durham are British Carboniferous "marbles" Rocks of the same age which take a high polish are common in Southern Belgium The "Petit Granit" of the valley of the Meuse is a dark-coloured Carboniferous limestone with corals showing up white on the dark ground There are many similar Carboniferous "marbles" in the United States

The "Purbeck Marble" of Swanage consists chiefly of shells of Paludina, a fresh-water gasteropod This rock takes a fairly high polish and has been used by way of contrast with the white and cream-coloured

stones for the columns of some of the cathedrals and churches of the South of England

Marbles, both as understood above and of the true metamorphic type, are common in North America Fine white statuary marble comes from Rutland, Vermont Marbles are, in fact, found in scores of places in the eastern mountain system and in the old rocks of the Laurentian region They include various kinds, red marbles, black marbles, white statuary marbles, and bluish varieties Marbles are also found in the western mountains in Colorado and California

Some of the famous marbles of antiquity and of the Middle Ages have come from Italy and Greece The famous Parian marbles from the Island of Paros and turquoise-blue marbles from Seravezza, Italy, are examples "Mandelato" shows yellow spots on a red ground and is found in Italy, and "Predazzite" is found in Predazzo in the Tyrol These are only examples selected from a great number of occurrences

Serpentine—This is a rock produced by the alteration of basic and ultra-basic igneous rocks It is tough, soft, and compact and of very variable colour, showing shades of yellow, green, and deep red, with streaks and veins and mottlings of various colours The name serpentine was given because of its supposed similarity to the markings on a serpent

There are four *chief* British localities the Lizard district in Cornwall, Valley near Holyhead in Anglesey, near Ballantrae in south-west Scotland, and Portsoy in Banffshire. A serpentinous "marble" occurs in Connemara, and is commonly made into charms and ornaments In consequence of its liability to attack by acids, serpentine is little used for outside work

Paving Stones and Road Metals.—The provision of paving-stones and setts for the streets of towns is now

an important problem, and the nature and source of some of the stones deserve the attention of the student of geography Hardness, durability, and reasonable lightness are the obvious desiderata in paving stones The last named quality may be illustrated by concrete examples which will serve as illustrations of general principles Some quarries were formerly worked in gabbro at Llanfaglan in Carnarvonshire The writer once visited these quarries to study the rock from the geological point of view A local farmer was much interested, and pointed out that the quarries had to be closed because buyers, who usually buy the rock by the ton, could get much larger bulk in other rocks for the same money Gabbro, of course, has a much higher specific gravity than granite, hence there is not so great a cubical content in a ton of the rock Another example was as follows A north-east Lancashire town experimented in the use of a German vesicular trachyte as a paving stone As the local surveyor pointed out, the vesicular character of the rock made it very light, and a ton contained a much larger number of average-sized paving stones than usual It would therefore be a cheap rock to use Unfortunately, it did not wear well under the heavy traffic of a Lancashire manufacturing town, and much of it had to be taken up and replaced by a more compact rock, the experiment was a failure

The examples quoted are from igneous rocks, the one a plutonic, the other a volcanic rock Igneous rocks now supply the bulk of paving stones Some famous localities are The granite of Criffel and Dalbeattie in south-west Scotland, the compact granites of Charnwood Forest in Leicestershire, the diorite of Penmaenmawr in North Wales, the dolerite of Pwllheli, North Wales, the Cleveland Dyke of North Yorkshire, and the

Whin Sill of Teesdale and Weardale There are very many other igneous rocks in other localities

Most of these rocks are also broken up for road metal Other famous road metals are the igneous rocks of the Lake District, especially Threlkeld, near Keswick "Rowley Rag" is a basalt from South Staffordshire, which has been very largely used in the Midland and Southern Counties

A quartzite rock from the Cambrian of the low hills near Nuneaton is used in large quantities for road metal in the English Midland Counties The chief quarries are on Hartshill

Paving stones and setts are frequently made from the harder beds of the Millstone Grit, especially are these used in the towns of Lancashire and the West Riding, where carriage for the stone is not heavy because of the short distance Rossendale, Whalley, and Barnoldswick are localities where Millstone Grit paving stones and setts are obtained Hard flagstones, frequently used in northern towns, are obtained from Rossendale and from the moorlands in the neighbourhood of Halifax and Bradford

The hard, dark-coloured limestone of the lower Carboniferous is frequently used for macadamised roads in the Pennines, where that type of rock is plentiful and easily obtained

Some Miscellaneous Uses of Rocks—Limestone is of very great importance in many processes Very large quantities are used in iron smelting, where it is added to the ore and the coke in the furnace so as to form a slag with the siliceous impurities in the ore For iron ores containing phosphorus, dolomitic limestone (that is, composed of magnesium and calcium carbonates) is used This is the famous "basic process" discovered by Thomas and Gilchrist

Lime is formed by roasting or "burning" limestone in a lime-kiln There is a big demand for lime to be used as manure on the land It is also largely used in the preparation of skins for the tanning processes in leather manufacture, for absorbing impurities in coal-gas manufacture, and in the manufacture of caustic soda from sodium carbonate or common soda Finally, it is used in making cement, mortar, etc, for building Portland Cement is usually made by heating together limestone and clay in proper proportions It will thus be seen that lime is a most important compound, and that the presence of limestone is one of the factors which determine the possibility of many trade processes

Millstone Grit—The name was originally given to this formation because millstones for grinding were made of its coarse, hard sandstones In the old corn-mills of the Pennine valleys, where the locally grown oats were ground into oatmeal, the grindstones were made of Millstone Grit These have long since passed out of use, except occasionally, but recently grindstones of Millstone Grit rock have been in demand for quite another purpose In a quarry at Colne, in north-east Lancashire, there were at one time numbers of large, round, that is, disc-shaped stones, some four or five feet in diameter and about two feet six inches in thickness These were for export to eastern Canada, where they were to be used for grinding timber into wood pulp A quarry in Millstone Grit near Keighley in the West Riding of Yorkshire was acquired by a North American lumbering company for the same purpose It is not apparent to the writer why suitable stone cannot be obtained nearer the lumbering region, it seems a long distance to take grindstones across the Atlantic It is, however, a good example of the interdependence and international character of industries in modern times

Another mention of Millstone Grit, and some of the similar grits of the Coal Measures, may be not out of place. Sheffield has long been noted for its cutlery. One factor which has made for its success in that industry has been the presence and abundance in the neighbourhood of grit-rock suitable for grindstones. In the earlier days of the development of cutlery manufacture, the advantage derived from suitable stone was emphasised by the occurrence of numerous streams, well fed by the abundant Pennine rains, which were used to drive the cutlers' grindstones.

Rock Salts.—In all the continents there are, in the present geological epoch, regions of internal or closed drainage, where the rivers do not reach the ocean, but pour their waters into salt lakes, where, on the whole, evaporation keeps pace with water supply. The soluble salts which are dissolved in the water of all rivers thus accumulate until the saturation-limit is passed and precipitation occurs. These internal-drainage lakes are, as may be expected, variable in area according to the season, or from year to year according to variation in rainfall. In the shallower, exterior parts of such salt lakes, precipitation of salts occurs regularly and large supplies are obtained from such sources. The Kara Borghaz (the eastern gulf of the Caspian Sea), for example, yields large quantities of salt. There is a regular current from the main body of the Caspian into that gulf, the bottom of which is encrusted with a layer of salt. A good deal of salt is obtained from the great Salt Lake in Utah, U.S.A. Lesser salt lakes, such as the Sea of Aral, the Dead Sea, and scores of others, yield either common salt (sodium chloride) or that salt mixed with others.

The water of the ocean contains, on an average, about three per cent. of dissolved salts; many of these

inland salt lakes contain much larger proportions The Great Salt Lake of Utah, U S A , contains 22 per cent , the Dead Sea of Palestine, 24 per cent , Lake Van in the Armenian Highlands, 19 per cent.

The different salts vary in proportion as magnesium salts are more soluble than sodium salts, and when the latter have already crystallised out, the relative proportions of the magnesium chloride will be increased Great Salt Lake contains eight times as much sodium chloride as magnesium chloride, but the water of the Dead Sea has more magnesium chloride than sodium chloride, with a large proportion of potassium chloride Lake Van contains sodium sulphate and sodium carbonate A lake which is very rich in carbonate of soda is Lake Magadi, situated about 60 miles south-west of Nairobi, in Kenya, East Africa Except in the rainy season it is a solid mass of crystalline sesquicarbonate of soda It is worked by the Magadi Soda Company Ltd

It will be clear that deposits of common salt or other salts will be formed in the strata of these regions, and that they will alternate with sands and marls formed in these internal drainage lakes We may therefore expect beds of rock salt to be found in those geological systems where similar conditions have held, and such salt deposits are quite common In New York State there occur salt beds in Silurian strata , these are beds of rock salt and gypsum which reach as much as 300 feet in thickness Carboniferous salt deposits are found in Michigan The lower beds of the famous salt deposits of Stassfurt in Prussia are Permian One boring has passed through varied salt deposits well over 3000 feet in thickness The salts found are sodium, potassium and magnesium chlorides, and gypsum The salt beds of the deep boring of Sperenberg, north of Berlin, are of Permian age The bore-hole passed through about 4000 feet of salt deposits

The salt deposits of the British Isles are in the Triassic rocks, as are some of the other salt beds of the Continent There are Mesozoic salts in Texas and the other Southern States. Tertiary salts are also found in the same region, one boring in Louisiana passing through 1800 feet of salts. The most famous Tertiary salt rocks are those of Wieliczska, near Cracow, in Poland These have been worked for ages, and the occupation of these salt mines by the Austrians in 1770 was one of the first important steps in that partition of Poland which has brought so much trouble to eastern and central Europe.

These immense salt deposits are of great geographical importance not only for the immediate salts obtained, but for the industries dependent upon them. Not only are these salts used in foods and for agriculture, but they form the raw material of many chemical manufactures Consequently such manufactures are found in, or near, large salt deposits The great chemical industry of the Mersey is located between the salt supplies of Cheshire, and the rich coal supplies of the South Lancashire coal-field, and where the Mersey, the Ship Canal, and the smaller canals offer ready facilities for inter-carriage and for import and export The Stassfurt salt deposits have been the foundation of the flourishing chemical industries of Saxony and the adjoining parts of Prussia

Finally, in this connection, we may notice a modern exceptional deposit, a rock in the true sense, which occurs in the desert region of western South America In the desert of Atacama in Peru is a deposit, chiefly of sodium nitrate ($NaNO_3$), occurring on the mountains up to heights of 5000 feet This surface deposit of such a highly soluble salt is, of course, only possible in a rainless region The beds of "caliche," as the impure salt is called, contain in addition iodides and potassium salts The origin of these extraordinary deposits has not yet

been fully explained Perhaps they are due to the decomposition of immense masses of sea-weeds, left to decay and alteration after the uplift of an old sea bottom on which had grown vast quantities of such weeds Other explanations have, however, been put forward These nitrate deposits, with their somewhat subsidiary iodides and potash salts are now important sources of nitric acid and of iodine, as well as potassium compounds

Rocks as Fuels

The formation of rocks from decayed vegetation was referred to in Chapter I A full account of the origin of peat and coal would take us too far into the science of geology As students of geography we may here glance at the economic aspect of the occurrence of these vegetable deposits

Peat—This occurs in large quantities in cool, temperate regions both on the wider moorlands and in the marshy lowlands Typical regions are the Southern Uplands of Scotland, the moors of the Midland Valley of Scotland, the broad grit moors of the Pennines, large areas in the Central Plain of Ireland, the Mountains of the North and West of Ireland, and the Low Countries, *i e* parts of Belgium, Holland, and Northern Germany Peat is cut and dried and is used for fuel, as litter for cattle and horses, and occasionally for the generation of ammonia by destructive distillation Compressed peat in the form of briquettes has been exported from Holland and North-west Germany in large quantities In the poorer parts of Ireland peat is the chief, almost the only, fuel used in the homes

Coal.—This valuable fuel occurs in layers or seams, which are often remarkably regular in thickness over wide areas These seams vary from a few inches to many feet in thickness A seam is usually worth working

if it is two feet or more in thickness and not very difficult of access. Seams which are actually worked vary considerably in thickness, as may be expected. Many famous British seams are from three feet to six feet thick. The famous Dudley Main seam in the South Staffordshire coal field has a thickness of twelve feet in places.

Coal-seams only form a very small fraction of the strata in which they occur. In the Burnley coal-field, in a generalised section of about 2360 feet of coal measures, there are twelve workable coal-seams of a total thickness of a little over 30 feet. The rest of the Coal Measures are shales, sandstones, fireclays, and very thin coal seams, the total coals, workable and unworkable, being about 54 feet.

In the British Isles there are few workable coal-seams in strata other than the Carboniferous system; the exceptions are a variable seam in the Jurassic system at Whitby, of rather poor coal, and a seam in the Jurassic of Brora in Sutherlandshire. These seams are of little value economically; they are of considerable geological interest, however.

Workable coals occur in geological systems from the Devonian to the Tertiary (*see* Chapter I.). The oldest real coal-seams known are found in Bear Island in the Arctic regions. A seam over three feet in thickness occurs there in the Devonian strata.

Coals of Carboniferous age are widespread and include the richest coal deposits in the world. They occur in Europe, Asia, and North America. Coals of upper Carboniferous and Permian age are found in Australia, India, South Africa, Argentina, and Chile, that is, in the Southern Hemisphere chiefly. They are a little newer than the chief coal-fields of the Northern Hemisphere.

Most of the small coal-fields of Central France are of

Permian age, as are those of Saarbrucken in Lorraine and those near Dresden and in Bohemia

Triassic coals are found in Virginia, U S A , and in Japan , and Jurassic coals occur in Britain as already mentioned, and at Funfkirchen in the Danube-Save region of south-west Hungary Cretaceous coals are worked in Washington, U S A , Alberta, British Columbia, New Zealand, and Japan

Tertiary coals are worked in Germany, Hungary, Japan, and the north-west region of the United States Rich coalfields of this age have been found in Spitzbergen

The more recent coals are usually of the variety known as lignite or brown coal These coals are less compact than the older coals, and usually still retain some of the original vegetable structure They are not so valuable as the coals of Carboniferous and Permian times

A map of the chief coal-fields of the world is given on page 226, from which it will be seen how well supplied are Europe, North America, and Eastern Asia

The different varieties of coal are of great importance The usual classification of coals as bituminous, cannel, and anthracite may not fully satisfy modern science, but from an economic point of view it is a convenient one

Bituminous Coal is the general name given to the coal burnt in our ordinary grates , it is stratified, splits readily along the bedding planes, soils the fingers on handling, partly melts in the grate in burning, and gives out gas and pitchy or bituminous matter It is usually somewhat shiny in appearance, especially along the bedding planes

Cannel Coal is not so plainly stratified , it breaks with a splintery, irregular fracture , is dull, black, and hard, and soils the fingers very little It burns with a crackling noise, and when heated gives off a good deal of gas When luminous coal gas was more in de

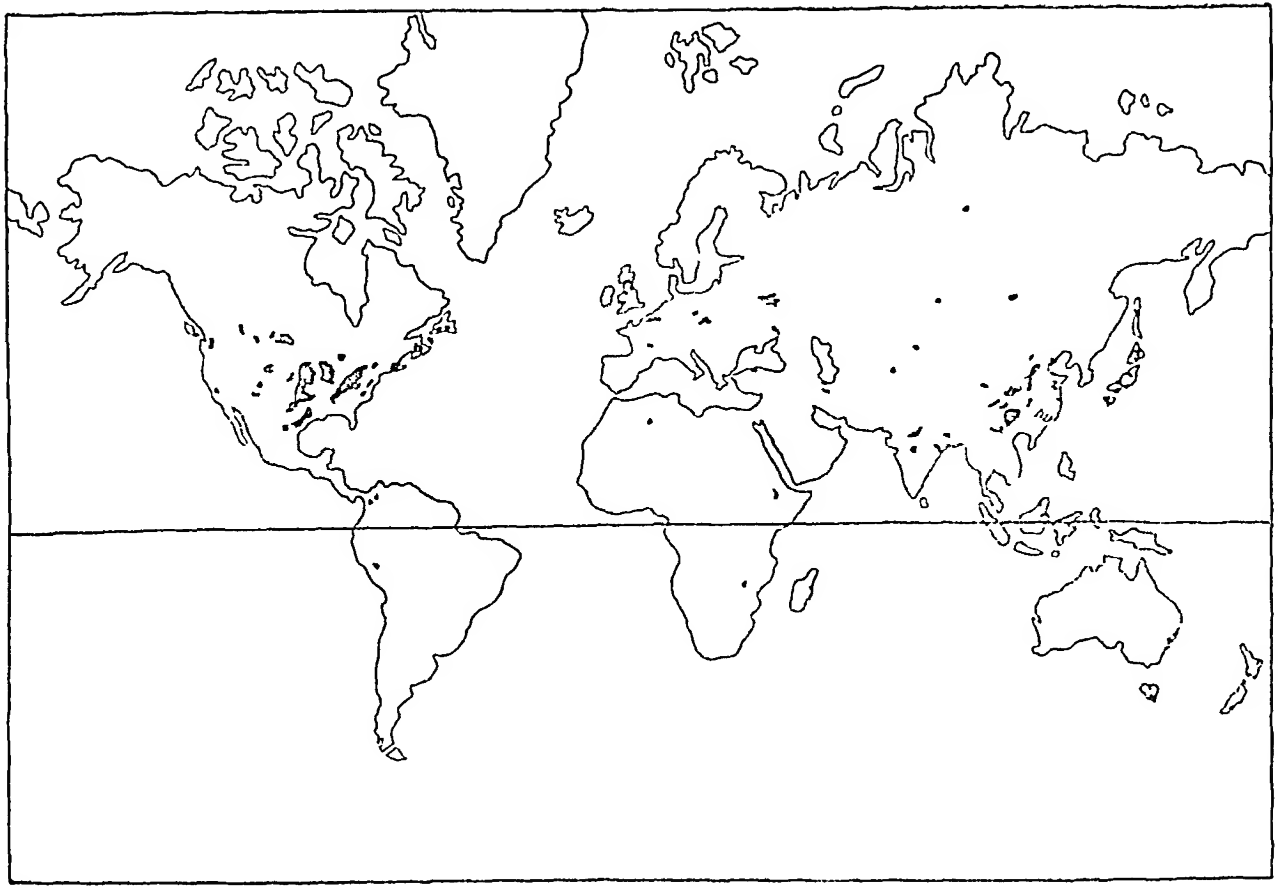

Fig 28.—The Coal Fields of the World, as at Present Known

Note the rich fields of the United States, China, Japan, India and W[illegible] C[illegible] [illegible]

mand, large quantities of cannel coal were used in the gasworks of the country

Anthracite is an important modification of coal occurring where there has been much folding of the strata It is probably not due to compression merely, but owes its characteristic properties in some measure to original peculiarities of composition It is the hardest kind of coal, has a shiny appearance, burns with comparative difficulty, emitting little or no smoke, and leaving very little ash It is of great value for warships which burn coal, as no trail of dense smoke is left behind It is now largely used in certain kinds of slow combustion stoves The supplies of good anthracite are limited to certain regions, South Wales, Fifeshire, the Donetz Basin, Pennsylvania, and Japan being among the best known The possession of large supplies of this valuable kind of coal is certainly a great asset to Britain The discussion of the question of its exportation to non-British countries belongs rather to politics than to geography

The question of the duration of our coal supplies has exercised the minds of statesmen, mining experts, and geologists This is of such importance that two Royal Commissions have sat and taken evidence within the last half-century On the whole, there is, perhaps, less alarm now than there was some years ago, because coal-seams are now so largely worked by boring through overlying strata such as the New Red Sandstone In the South Yorkshire coal-field the actual mining field now extends far beyond the limits of the coal-field as marked on a geological map Large supplies of coal are now obtained from these "buried coal-fields" The limit of such operations is reached when the dip of the coal-seams carries them down to such a depth that difficulties of ventilation and expense of lifting the coal

become too great, and the working does not pay Coal-seams are now worked at a much greater depth than formerly

The coal output of the world now amounts to about 1000 million tons per annum In the year 1933 the United States of America contributed about 33 per cent of this output, Great Britain about 20 per cent, Germany 10 per cent, and France $4\frac{1}{2}$ per cent (*See* Note)

The British Isles exported nearly £33,000,000 worth of coal and coke in 1933 The total value of the coal obtained was well over £130,000,000 Nearly a million persons are employed in the British coal mines in normal times

In the closing part of this chapter brief mention may be made of the remarkable influence of coal supplies on the distribution of population Coal is so largely used, not only for fuel in the ordinary sense as a source of heat energy but for gas manufacture, and for the production of coke for smelting, that abundance of it may be reckoned as the first necessity of a busy industrial region In the countries where manufactures employ large numbers of people the thickly peopled regions are very often in or near coal-fields The student should compare a map of the distribution of the population in England in say 1700, with the distribution in 1900, and then place the map showing the latter side by side with a map of the coal-fields, the correspondence of the two maps is striking The distribution of coal supplies will come up again in connection with the smelting of metals

There is some possibility that the pre-eminence of coal may be challenged in the future, as coal becomes dearer, manufacturers are compelled to look out for other sources of energy, and electricity generated from waterfalls in mountain regions is being more and more

used. There may possibly be a new distribution of great industrial regions in the future, the dominant factor may be abundance of water-power and coal may take a second place. That phase of industrialism is not yet however.

BIBLIOGRAPHY

See end of Chapter XII

NOTE

The economic and financial crises which have occurred during the last few years in almost every country in the world have restricted international trade and affected output in many mineral and vegetable commodities. The figures given in this and subsequent chapters are therefore liable to vary from year to year. Recent returns can always be obtained from the current issues of *Whitaker's Almanac*, *The Statesman's Year Book*, and from the publications of the Board of Trade.

CHAPTER XII

ECONOMIC GEOGRAPHY OF THE ROCKS (*Contd*)

ROCK CONTENTS

In the preceding chapter the uses of the rocks themselves were discussed, we now turn to some of those substances of economic importance which are obtained from the rocks Rocks as fuel were considered in the latter part of the chapter, we will commence this chapter by some study of those fuels which occur as occasional constituents of certain rocks

Petroleum and related Substances—From the rocks of many parts of the world gaseous, liquid, or solid substances which will burn readily are obtained They are practically all compounds of carbon and hydrogen, and are therefore generally spoken of as hydrocarbons They are found in sedimentary rocks of all ages from Cambrian to Recent, but the mode of origin is still a matter of some uncertainty When a boring is put down into strata containing these hydrocarbons, gases are often set free and come rushing out with considerable force Liquid hydrocarbons have also been forced up with such violence that the boring apparatus has been hurled away

Petroleum now forms one of the most important supplies of fuel, the increased use in motor-cars, aeroplanes, and for men-of-war and in other ways, has made a big demand, especially for the liquid fuel. In

some districts the gaseous and liquid hydrocarbons are used in the place of coal, coke, and coal-gas, for example, in gas engines and for the smelting of iron Large quantities of these rock-oils are also used for the extraction and preparation of different kinds of fats Both animal and vegetable fats and oils are readily soluble in the hydrocarbon oils

The chief countries from which petroleum is obtained at present are the United States, Venezuela, Russia, Mexico, Persia, Rumania, the Dutch East Indies, and Colombia The oilfields of the United States are the richest in the world yet known, and occur in areas of Palæozoic rocks in the eastern region in Pennsylvania, New York, Ohio, and Indiana The rich fields of western Pennsylvania and New York have given rise to a marvellous development of industries of many kinds in which large supplies of fuel are necessary Much petroleum is used in the immense iron industry of Pittsburg and district Petroleum is obtained from newer strata in Texas, Oklahoma, Colorado, and California

The great wealth of North America in petroleum and natural gas may be illustrated as follows the value of the natural gas yielded by the United States in 1933 was £75,000,000, while the petroleum yield was over 900,000,000 barrels of 42 gallons The leading states were California, Texas, and Oklahoma, in the order named The United States yielded about 60 per cent. of the world's total in 1930, followed, at a great distance by Venezuela, Russia, Mexico, Persia, and Rumania Alberta is thought to be capable of a considerable production, at the time of writing it is about one million barrels a year, which seems small by the United States standards, but development is proceeding steadily

The Russian Oil Field —The great Russian oil-field

lies on both sides of the Caucasus mountains, the richest part being in the peninsula of Aspheron where those mountains extend into the Caspian Sea Baku is the "centre" of the industry Burning oils have been known there for hundreds of years, but the great development of the oil-fields has been of quite recent growth Many of the wells are "free-flowing," that is, no "pumping" is necessary Single wells have been known to yield more than 1,000,000 gallons of oil per day for many days together A pipe nearly 600 miles long has been laid down to convey the oil from Baku to the special boats at Batum

The Caucasian oil-region extends into Persia and Turkestan The Persian oil-field is mainly in the region of the upper Karun River, and a pipe line brings the oil down to the coast

The Polish and Rumanian oil-fields are similarly related to the Carpathian fold-mountains, as the Russian oil-wells are to the Caucasus The most productive area is on the north-east of the great curve of the mountains from Kolomea to Jaslo Other rich wells are in the Kolozsvar district in Transylvania, and in the Ploesti district on the opposite side of the mountains in Rumania

Solid hydrocarbons are obtained from the same oil-regions as the liquid and gaseous compounds, and from a few other places where the latter are not obtained in any great quantity The solid products are obtained in the arts as residues from the fractional distillation of the oils, and in nature they are probably the result of evaporation of the more volatile portions of the naturally occurring hydrocarbons A series can be drawn up from the most volatile hydrocarbons of the paraffin and olefine series of the chemist to the most solid asphaltum *Paraffin scale* and *vaseline* are well known from the United States,

and from the Caucasus is obtained solid *bitumen*, a hydrocarbon mixture which is now widely used *Asphalt* or *asphaltum* has long been known from Switzerland, where it is obtained from the Val de Travers The most famous occurrence of asphalt to-day is the "Pitch Lake" in the Isle of Trinidad, a lake of semi-molten, hot pitch, half a mile in diameter and of unknown depth

Hydrocarbons from Oil-Shales—In the Carboniferous system of the Midland valley of Scotland there occur shales known as oil-shales or bituminous shales They have been worked in Linlithgow, Midlothian, and West Fife, and to a lesser degree in the coal-fields farther west The shales are heated in retorts, and the oils distilled over and condensed in receivers The products of lower boiling-point, which, of course, remain liquid at ordinary temperatures, are known as *Paraffin Oil*, their general composition is much the same as the petroleums from the natural oil-wells, and they are used for the same purposes The solids, which are left after evaporation of the more volatile portions, are usually called simply Paraffin Candles are made from these solid Paraffins, and there are many other uses for them In New South Wales similar bituminous shales yield the *kerosene* which is used for lighting many a settler's home in Australia

Metals and Ores of Metals in the Rocks

The distribution and mode of occurrence of metals is of great importance in the study of economic geography Metals are of such great importance in modern life, and so many of man's activities depend directly upon them, that their distribution exercises a very great influence upon the industries of a country and upon the distribution of population The subject may be

illustrated by reference to the more important and better known metals, such as gold, silver, copper, lead, zinc, tin, and iron , though, of course, many other metals are of great importance to man, and the importance of some of the rarer metals (such as tungsten, for example) seems to be increasing rapidly

It is obvious that the occurrence of rich iron ores in conjunction with fuel to smelt them not far away will probably lead to a great concentration of population, and to the establishment of varied steel industries ; examples of this are seen in Central Scotland, Staffordshire, Westphalia, and the Pittsburg region in the Appalachians

The discovery of gold has brought about sudden and extensive migrations, and eventually has led to the settled colonisation of the gold regions , the well-known " gold-fever " of California in 1848–50 and of Australia in 1851–2 led to a great rush of emigrants to those countries Many of those failed as gold seekers, but settled as agriculturists or as traders , and some of those who made fortunes out of gold bought land and became wealthy, colonial landowners The most northerly railway in the world—that from Narvik on Ofoten Fiord through Gellivara to Lulea—was determined by the rich magnetite deposits in Swedish Lapland The northern part of the railway is actually within the Arctic Circle It is safe to say that the Yukon district, in North-Western North America, would have waited long for colonisation had not rich gold-finds attracted men to that inhospitable land

The metals rarely occur in the native or free state, the chief exceptions being gold and platinum , usually they are found combined as sulphides, oxides, carbonates, or silicates These compounds of the metals are

known as ores An ore may be defined as a compound of a metal from which the latter may be extracted in quantities which pay It is clear that a compound which would not pay to-day may pay in future if the metal is more in demand, or if improved processes of extraction are discovered An example may illustrate this latter point The rocks of the Jurassic escarpment of Britain, and the rocks of the same age in Lorraine and Luxemburg contain large quantities of iron compounds, but these were difficult to work on account of their large proportion of the troublesome "impurity" phosphorus until the discovery of a new process by Thomas and Gilchrist in 1879 Since then these ores have become very important sources of iron, and now support an enormous industry, especially on the Continent

There is no general rule as to the occurrence of metals in different kinds of rocks and in association with different land-forms, but it is possible to make some important, broad statements

Sedimentary Rocks.—The more modern sedimentary deposits contain few metals or metallic ores, the chief exceptions are gold which has been washed into alluvial deposits as the result of the disintegration and denudation of igneous and metamorphic rocks Owing to the high specific gravity of the metal it has become more concentrated in these river deposits as the lighter rock particles have been continually washed away. Such deposits are known as "placers," and placer-gold is often the first source of gold in a new region After the exhaustion of the alluvial deposits the gold is traced to its source in the "country rock," from which it is obtained first by crushing, and by extraction from the crushed rock by means of mercury or sodium and potassium cyanides Placer-mining

for gold still obtains on the western side of the American continent from California to Alaska Much of the gold of antiquity was obtained from the river-gravels of Asia Minor and Egypt, though gold was also obtained by mining in solid rocks It was from the sands of its rivers that the gold of the famous Gold Coast of West Africa was long obtained Now there are gold mines "up country" in the British possessions in that region

Platinum is obtained similarly from the sands of the rivers in the Ural Mountains and in Colombia, other heavy metals, such as iridium and osmium, are associated with it in the native condition

Tin-Stone—that is, crude oxide of tin (SnO_2)—is often obtained in the form known as stream-tin, because so much has been found in the river-gravels of Cornwall It is obtained similarly from the river-gravels of the Straits Settlements, and stream-tin in considerable quantities in the rivers of Northern Nigeria, Bolivia, and other regions

Ores from the Sedimentary Rocks—The Mesozoic and Palæozoic rocks, especially the limestones, contain more metallic ores than the Tertiary rocks Iron ores were formerly mined in the English Weald from the Lower Cretaceous Wealden Beds These ores formed one of the chief sources of British iron up to quite modern times, when the furnaces ceased to be remunerative in face of the competition of the furnaces situated on or near the coal-fields The last furnaces went out of action about 1857, and London still contains many examples of iron from that district It is said that the iron railings of St Paul's Churchyard are almost the last sample of the iron smelted in the Weald There may be a reopening of the mines in the future, but the ore will probably be taken to the coal-fields

Or, now that coal is being obtained in some quantity from the Kent coal-field, the whole position may be modified, and south-eastern England may again become an iron-smelting region

Iron ores are found in immense quantities in the Jurassic rocks of Britain, where they are interbedded among the other strata There are four chief localities —Cleveland, North Lincolnshire, Northamptonshire, and Oxfordshire The ores of Cleveland are said to be due to alteration in strata subsequent to deposition, the lime of the calcareous deposits having been replaced by iron As was mentioned previously, similar ores are found in the Jurassic rocks of Lorraine and Luxemburg, where a great mining industry has sprung up

Iron ores are found in the Carboniferous Limestone of the Lake District rim, especially near Cleator Moor on the north-west side, and near Ulverston, Dalton, and Millom on the south-west side Similar ores are found in the Carboniferous Limestone of the Forest of Dean and of North Wales, but not in such large quantities as in Furness and West Cumberland

Iron ores are also found in the shales of the Coal Measures, especially in Central Scotland, in Durham, in the Yorkshire and Derbyshire Coal-field, in Staffordshire, in the Severn Coal-fields, and in South Wales, but these ores are little worked now except in North Staffordshire and Lanarkshire The quantity of iron ore formerly obtained from the South Staffordshire district has been said to be greater than that found in any similar area in the same thickness of strata

Iron ores are found in the Palæozoic rocks of the United States The Clinton Limestone of the Appalachians furnishes much ore, from Alabama to Central New York This limestone is of Silurian age, and is

comparable to the Wenlock Limestone of Britain In Pennsylvania iron carbonate or black-band ironstone occurs in the Carboniferous system, just as it occurs in the British Coal Measures The famous ores of the North of Spain, exported in such large quantities from Bilbao and Santander, come from the Carboniferous Limestone

Ores of lead and zinc are also largely obtained from limestone, where they often occur in irregular masses in the joints and cavities, which are so common in limestone The lead and zinc ores of the Carboniferous Limestone of the Northern Pennines may be quoted as examples Lead ores have also been obtained in considerable quantities in the Derbyshire Carboniferous Limestone, and in North Wales The same metals are found in limestone in the Rocky Mountains The zinc deposits of Upper Silesia, which are also in sedimentary rocks, are probably the largest sources of that metal in the world The metalliferous deposits of the upper Oder region have been the cause of much difficulty in settling international boundaries

Igneous Rocks are not, as a rule, rich in paying ores Compounds of practically all the metals may be found in these rocks, but they are often present in small quantities or in combinations from which the metal would not be easily and profitably extracted Occasionally in basic igneous rock either on the margin or the centre of a plutonic or intrusive mass there is so large a proportion of magnetite that the rock becomes a paying ore Some of the well-known Scandinavian ores are thus found in igneous masses For example, one of the rich deposits at Taberg near Jonkoping in south-eastern Sweden is the middle of a large mass of altered basic igneous rock

Gold is disseminated through some granites, syenites, and diorites , the erosion of these igneous rocks leads to

the accumulation of the precious metal in the alluvial deposits formed from the wear and tear of those plutonic rocks, as already described

Notwithstanding these examples, workable metallic ores are only found, as a rule, in igneous rocks as a result of alteration, or in veins which have penetrated these rocks Such vein deposits are little different in relationship from those found penetrating sedimentary and metamorphic rocks

Metamorphic Rocks vary very considerably in their yield of metals In such a region as the Highlands of Scotland metallic ores are by no means very plentiful, but in the similar rocks of Scandinavia some rich deposits of ore are found The metamorphic region round Lakes Superior and Michigan contains some of the richest iron ore known, an immense mining industry is now located there, much of the ore being sent to the Ohio-Pennsylvania district Metamorphic rocks in the Urals are also rich in iron ore As examples of rich metallic deposits in metamorphic rocks we may quote the famous "Iron-mountain" of Gellivara in Lulea-Lappmark in north Sweden, which is 500 feet high, and is 3 miles long by 1½ wide The ore is magnetite with chromite The rich ores of Dannemora also occur in schists, as do some of the ores of southern Sweden

Metamorphic rocks are also rich in vein ores in some regions, the eastern Appalachians and the Ozark Hills being examples from North America Gold is disseminated through some of these rocks, especially the quartzites Famous examples are the rich quartzites of Ballarat, Victoria, possibly the richest gold area for its size in the world, and the quartz rocks of the Transvaal

It will thus be seen that there is considerable variation in the yield of ores in the three great classes of rocks, and it is similarly impossible to say of the rocks of any

geological systems or of any land forms, that they will or will not yield metallic ores in paying quantity Some fold-mountains of comparatively modern age are rich in metals, as in the case of the Andes , on the other hand, the Alps are singularly lacking in useful ores The Caucasus, belonging to the same system of fold-mountains as the Alps, are, however, rich in metals The old worn-down Armorican and Variscan fragments are rich in various metals, but again there is considerable variation in the yield of different districts Fractured crust-blocks, especially on their exposed and dissected margins, are usually rich, as may be seen in the crust-blocks of Europe and North America The rims of the Meseta have often been quoted , mercury at Almaden, lead in the east, copper in the south, tin in the north-west, iron in the north, are among the ores found Where a crust-block abuts against a fold-mountain system metals seem to be particularly abundant, as is suggested in Spain, the Hungarian Ore Mountains, Nevada, U S A , Mexico, and elsewhere

After this consideration of the circumstances of the occurrence of metallic ores, it may be advisable to give some attention to the yield of different regions as expressed in the commoner geographical terms A few of the more important metals are taken and illustrated from the published statistics

Gold —Approximate value of the output of Gold in 1932, £100,000,000

(1) South Africa, £48,000,000, or 48 per cent of the world's total
(2) United States, £9,500,500, or 9 5 per cent of the world's total
(3) Canada, nearly £12,000,000, or 12 per cent of the world's total

Other important producers are Australia, Russia, Mexico, Southern Rhodesia, and India

It will be seen that South Africa (chiefly the Transvaal), the United States, and Canada were responsible for nearly three-fourths of the world's output in 1932 The relative proportions fluctuate somewhat That of Australasia has shown some tendency to decrease during recent years, while that of Canada has increased

Silver —The chief regions are the plateaux of Mexico and the United States (the latter including Nevada, Colorado, Montana, etc), Canada, Australia, and India The output in 1932 was, in troy ounces, in round figures, as follows

The world's total	170,000,000
Mexico	72,000,000, or 42 per cent
United States	24,000,000, or 14 per cent
Canada	17,000,000, or 10 per cent
Australia	7,100,000, or 4 2 per cent
India	5,000,000, or 3 per cent

Copper —The great plateau of Western North America (with the adjacent mountains) again leads, more than four-sevenths of the world's production coming from that region, other important sources are Spain, Japan, Australasia, and Chile The approximate output in 1933, in tons of metal, was as follows

United States	410,000, or 41 per cent
Chile	160,000
Belgian Congo	90,000
Canada	130,000
Japan	70,000
N Rhodesia	100,000

The commanding position of the United States is obvious

Tin —The ores of this metal are very local in their distribution, a very few localities producing most of it

The Federated Malay States, Bolivia, the Dutch East Indies (Banka and Biliton especially), Nigeria, Siam, and China, produce the greater part of it The yield in 1933 was approximately as follows

The world's total	85,000	tons of metal
Federated Malay States Settlements	23,000	,,
Bolivia	15,000	,,
Dutch East Indies	14,000	,,
Nigeria	4,000	,,

The quantity from the different sources fluctuates very considerably from year to year For comparison we may note that the British Isles produce about 1600 tons per annum

Lead—The chief countries producing lead are the United States, Mexico, Australia, Canada, Spain, and India, in the order named The total output of the world for 1933 was estimated at over 1,000,000 tons The countries named contributed as follows

United States	265,000	tons
Mexico	127,000	,,
Australia	210,000	,,
Canada	117,000	,,

The British Isles produced about 6,100 tons in 1933, valued at £100,000 in round figures

Nickel—This metal is being increasingly used for the manufacture of crucibles, coinage, and some domestic utensils It is also a constituent of some white metal alloys, as well as some alloy steels It is obtained to the extent of over 90 per cent from the mines of Sudbury, Ontario The only other source of great importance is the French colonial island of New Caledonia The 1933 figures were world output (in tons of metal), 40,000 tons, Canada, 36,000 tons, New Caledonia, 2600 tons

Zinc.—The six leading producers of zinc ores are United States, Mexico, Australia, Germany, Poland, Canada, producing quite three-fourths of the world's total

The world's total in 1933 was about 1,000,000 tons (in terms of metal)	
United States	290,000 ,,

It has already been remarked that Upper Silesia, partly in Poland, partly in Germany, is one of the richest, perhaps the richest, limited region for zinc in the world

Iron Ore—The three leading countries in the output of iron ore in 1933 were the United States of America, France, and the British Isles, in the order named

In 1933 the production of ore was as follows

Total for the world	128,000,000 tons
United States	48,000,000 ,,
France	35,000,000 ,,
British Isles	7,460,000 ,,

Pig Iron—The proportion of pig iron—that is, the product of the first smelting of the ore—is not quite the same for the countries Germany and the British Isles now find their supplies of ore much short of the demand, and large quantities are imported In 1933 the United States produced 9,000,000 tons of pig iron out of a total for the world of 48,000,000 tons, that is, 27 per cent, Germany, 5,200,000 tons, or 11 per cent, and the British Isles, 4,000,000 tons, or about 9 per cent of the whole

Four minerals which are of considerable importance are asbestos, mica, the group of phosphates, and sodium nitrate

Asbestos—This name is now made to include a group of closely allied minerals which are obtained almost exclusively from metamorphic rocks Asbestos

is distinguished by its fibrous structure and its resistance to fire and to chemical change It is widely used for the manufacture of fireproof packings for boilers, steam pipes, and brakeband linings, for firemen's clothing, fireproof curtains, linings for furnaces, floor boarding, roof shingles, etc , where the fireproof character is important Asbestos in various forms is now the basis of a big and varied industry

The world-production of asbestos in 1933 was 230,000 tons, of which Canada yielded over 160,000 tons, or 70 per cent of the whole, largely from Quebec province Other important contributors were Southern Rhodesia, Union of South Africa, Russia, and Cyprus The British Empire yielded 90 per cent of the world's output

Mica —This is a group of minerals which includes four or five principal members , all the types are alike in possessing extremely fine cleavage, and most of them are tough, flexible, and resistant to fire , mica is also a bad conductor of electricity Two of the species, muscovite and phlogopite, are widely used in many arts and manufactures

The four chief sources, at present and for some years back, are United States of America, India, Canada, and the Union of South Africa

Phosphates —These are in great demand chiefly as manures, some being put on the land directly, in the powdered condition, but they are more often converted into superphosphate which acts much more rapidly It is estimated that for some years back the production of phosphate-rock has amounted to about 10,000,000 tons a year, of which the United States are responsible for from three to three and a half million tons Other regions which produce big quantities are Tunis, Algeria, the French zone of Morocco, Nauru Island in the Pacific , Egypt, and Christmas Island (Indian Ocean)

Sodium Nitrate—Chile supplies the world with mineral nitrates (impure nitrate of soda), the amount produced in that country in 1933 being half a million tons India produces about 6000 tons of nitrate of potash a year, and no other country or region seems to reach 1000 tons of mineral nitrates a year The Chilean deposits occur in the northern, almost rainless zone of that country, in the districts of Antofagasta and Tarapaca, where the nitrate zone has a Pacific coast-line of about 450 miles As a by-product of the preparation of the nitrate there is obtained iodine, and about 80 per cent of the world's consumption of iodine comes from this source

Until a few years ago Chile had almost a monopoly of the world's nitrate production, now synthetic nitrates are produced in Norway, Sweden, Germany, England, and the United States in increasing quantities, and the Chilean monopoly holds no longer

Rocks and Water Supply

A most important part of the rock contents is water, which is contained in greater or lesser quantity in all rocks Some rocks are obviously more permeable than others sands and sandstones allow water to pass through between the grains of which they are composed, and in the case of the sandstones along the bedding planes and through the joints, which are always present Limestones are not so permeable through the mass of the rock, but they are usually well-jointed and water passes readily along these joints, widening them in course of time because of the solubility of limestone in natural waters Clays, shales, and slates are much less permeable, in many cases so completely impermeable that little or no water can pass through the rock across

the direction of stratification, but only along the bedding planes and through occasional joints Igneous and metamorphic rocks vary very considerably, but as a rule they do not allow much water to pass except through joints and other fissures

The water which falls as rain or snow upon the land may be evaporated, or it may run off, or some may penetrate into the rocks below This *underground water* may travel for some distance below the surface, and may be there for a long time before it reaches the surface again. It is the porous rocks such as sandstones that offer the least resistance to the gradual passage of this underground water The water stored or flowing in rocks is of vast importance, because it often supplies country houses, sanatoria, villages, and even occasionally considerable towns The water may be reached by boring, or it may come out in the form of springs. The latter case may be illustrated first On an exposed surface of rock, water is often seen to be dripping out gradually and in small quantities, but frequently there is a considerable outflow, and we call that a spring

Springs may result wherever the water falls upon the surface of porous strata which have an impermeable bed below The descent of the water there is arrested, and it then flows in a lateral direction If the junction of the impervious clay or shale and the porous sand-

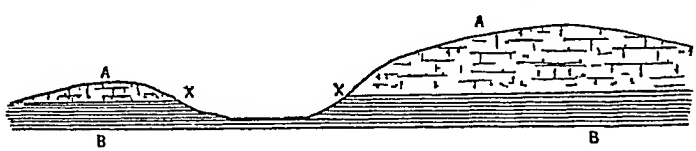

FIG 29 —A FREQUENT CASE OF THE ORIGIN OF SPRINGS

Sandstone, A—A, which is freely permeable, overlies shale, B—B, which is comparatively impervious to water Springs result at X—X

stone occurs on a hillside, a line of springs may clearly mark out that junction

A line of springs often marks the position and direction of a fault Water descends through porous beds

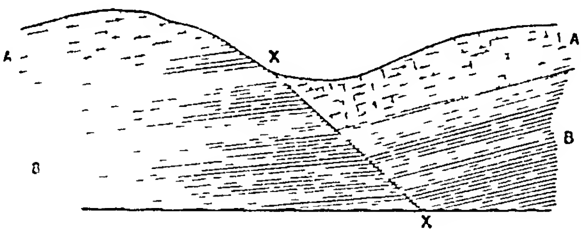

FIG 30—A SPRING WHICH IS DUE TO A FAULT

At the fault X—X permeable sandstone A has been brought against impervious shale B Rain which falls on A will penetrate the sandstone and will flow out in springs at X

until it reaches a clay or shale, then it flows laterally until it comes to the fault, when it ascends under the pressure of the head of water in the rocks, and flows out at the surface in a spring or series of springs

If the spring occurs in a region wherein there has been much faulting, or much folding, and especially if it is a region where igneous action has recently died out and where, consequently, heated rocks may lie at no great depth, then one or two interesting modifications of springs are possible—hot springs and mineral springs The water of hot springs often rises along fault planes, which thus give opportunity of communication with heated regions at some distance from the surface Mineral springs contain dissolved salts of various kinds, many of which are of considerable medicinal value In the neighbourhood of these mineral springs sanatoria are built and baths are fitted up, or "pump rooms," where the water may be drunk The water of some very famous medicinal springs is bottled and exported in

large quantities Many hot springs are also mineral springs

Artesian Wells —Another typical case of water being obtained in large quantities from the rocks is that from Artesian wells, so called because they were first of all developed in the district of Artois in France, where the rocks occur in a typical basin The best known Artesian wells occur where the strata form a syncline, and where permeable water-bearing beds lie between impermeable strata The London basin may again be mentioned as an example The porous chalk dips from the North Downs under London to reappear in the Chilterns, under the Chalk is the Gault clay, over much of the Chalk area lies the London Clay Many a London boring has been put down through the London Clay to reach the water-bearing Chalk, and so obtain some of the water which has fallen as rain on the Chilterns or North Downs *See* Fig 6, Chapter IV p 65

It is not necessary that the rocks form a syncline, a monoclinal fold may also furnish a good water supply if the other conditions obtain, that is, if a permeable formation occurs between impermeable beds

Borings of this kind are now very common and are found all over the world In the various basins of Europe there are now hundreds In the United States they are very common, the chief regions being the Gulf Plains and the Atlantic Coastal Plains, the Upper Mississippi Valley and the Plains of Dakota and Kansas In some desert or semi-desert regions such wells supply water not only for drinking but for irrigation also, in the great basins of the Western States, in the Sahara, in Mesopotamia, and in the "Dead Heart" of Australia, for example

In Queensland is one Artesian boring over 7000 feet deep There are now over 5000 borings in Australia,

and they have effected a wonderful change in the drier interior of this great Commonwealth

Artesian wells furnish water for works of various kinds, for small towns and villages, for country houses, and, as already mentioned, for irrigation Various salts are always present in some quantities, and some times, as in the Colne Valley works in the London Basin, the water has to be softened for domestic purposes But such water is almost always wholesome and far preferable to that from shallow wells

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SECTION B

THE PRINCIPLES OF CLIMATIC GEOGRAPHY

CHAPTER XIII

THE ATMOSPHERE WINDS, RAINFALL, AND TEMPERATURE

We must now pass from the lithosphere to the atmosphere, with incidental references to the hydrosphere As we have seen over and over again, climate plays a great part in earth sculpture, it also determines the conditions of animal and plant life, and is supremely important in connection with the economic development of different regions of the world

Climate is the average or prevalent weather condition of a place or a region, or, in other words, the average condition of the atmosphere There may be included in its study the following elements amount of sunshine, temperature, atmospheric pressure, direction and force of winds, moisture in the air and rainfall All these are inter-related, and it is quite impossible to isolate the study of any one from that of the rest

The Atmosphere

It is necessary to summarise our knowledge of the atmosphere This surrounds the earth to a depth of

possibly 200 miles, though the greater proportion of its mass is confined within a very few miles of the surface of the lithosphere About nine-tenths of the mass of the atmosphere is contained in the lowest 12 miles

The atmosphere may be regarded as a mixture of nitrogen and oxygen in the proportion of four volumes of the former to one volume of the latter There are also present small proportions of carbon dioxide, argon, and other gases, but the argon may for our purpose be grouped with the nitrogen, with which it was confused until the last twenty years Carbon dioxide is of more importance, though it concerns the biologist more than the geographer There is also present water-gas or vapour in very variable quantities, and this is of supreme importance to the geographer

All these constituents are intimately mixed together, and the mixture obeys the ordinary gas laws For example, the volume of a given mass varies directly as the absolute temperature and inversely as the pressure

To accumulate accurate data for the determination of the climate of a place the elements mentioned above must be measured at sufficiently frequent intervals Hence the thermometer, barometer, rain-gauge, and other instruments are the working tools of the meteorologist or student of climate and weather A description of the apparatus belongs to the science of physics ; the geographer is concerned with the results

The Pressure of the Atmosphere—At the sea-level the average pressure of the atmosphere is equal to that of a column of mercury 760 mm or 29 9 inches high At different places on the earth's surface, and at the same place at different times this pressure is found to vary between about 28 and 31 inches

The pressure will clearly diminish from the surface

of the lithosphere upwards, because at any great altitude it is due to the weight of the air vertically above the surface under consideration Near the earth's surface diminution of pressure is at the rate of about one inch of mercury for every 1000 feet, but at higher elevations the pressure does not diminish so rapidly

It has been stated that nine-tenths of the mass of the atmosphere lies in the lowest twelve miles, but it is perhaps of more importance to the geographer to emphasise the fact that most of the water vapour present is found in the lowest 6000 feet

Water vapour, or water in the gaseous condition, is much lighter than dry air, the relative densities being approximately 9 14 4, hence the greater the quantity of water vapour present at any time or place the lower is the density of the air, and the less is the pressure shown by the barometer From this follows the familiar generalisation that the lower the pressure the greater is the proportion of aqueous vapour in the air

There is one other physical property of the atmosphere as a mixture of gases that the geographer has continually to bear in mind It is highly compressible and as readily expands When air is compressed heat is generated and the air is warmed, unless heat is at the same time removed in some other way Conversely, when air expands there must be cooling, unless heat is supplied from some other source at the time the expansion is taking place Thus warming owing to compression, and cooling due to expansion play a most important part in weather phenomena

Yet another important physical property of the atmosphere is its relation to light and heat rays Air is obviously transparent to light rays, and it has been established by experiment that dry air is almost perfectly transparent to rays of all wave-lengths, it is

by the water vapour, carbon dioxide, and various dust particles in the atmosphere, and especially by that condensed water vapour which forms fog, mist, and cloud The lower layers of the atmosphere are also warmed by contact with the land and sea surfaces

The temperature of the atmosphere consequently diminishes with altitude, the average rate being about 1° F for every 300 feet of ascent This diminution seems to continue until a height of about six or seven miles is reached, when what has been called the *stratosphere* is reached, in which there seems to be no farther fall of temperature with increasing distance from the earth's surface The study of this upper layer is yet in its infancy, and though its properties may yet be shown to exert very considerable influence upon the climatic phenomena of the more accessible regions, it lies outside the scope of this book

We may now turn to those factors which are responsible for departure from uniformity of distribution of heat on the earth's surface If the earth were always turned similarly towards the sun, and if its surface were of uniform character everywhere, climate would vary with latitude, and the zone of greatest heat would correspond with the geographical equator

Owing to the inclination of the earth's axis at an angle of 23½° to the plane in which it travels round the sun, the vertical sun changes its position between limits of 23½° on each side of the equator The sun is overhead in lat 23½° N at the northern summer solstice on 21st June It is overhead in lat 23½° S on 21st December On 21st March and 23rd September it is overhead at the equator The circles of latitude parallel to the equator and at an angular distance of 23½° are called the Tropic of Cancer in the Northern Hemisphere, and the Tropic of Capricorn in the Southern Hemisphere

The sun is never overhead outside these limits These relations are indicated in the diagram

The midday angular elevation of the sun at any place on the four important dates mentioned can readily be found if the latitude is known Thus in lat 51° the height of the midday sun on 21st March is (90°–51°) = 39°,

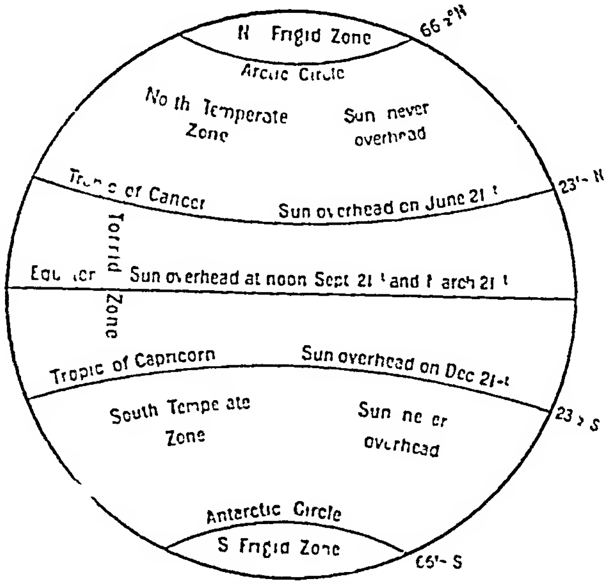

FIG 32 —DIAGRAM OF THE "ASTRONOMICAL ZONES" ON THE EARTH S SURFACE

on 21st June it is $90°-(51°-23\frac{1}{2}°) = 62\frac{1}{2}°$, on 21st December it is $90°-(51°+23\frac{1}{2}°) = 15\frac{1}{2}°$

For New York, lat 41° N, the heights are 21st March and 23rd September, 49°, 21st June, $72\frac{1}{2}°$, 21st December, $25\frac{1}{2}°$ For Petrograd, lat 60° N, the three heights are—30°, $53\frac{1}{2}°$, $6\frac{1}{2}°$

It is clear that the difference in duration of daylight between the days of summer and winter is

greater the higher the latitude The average height of the sun is greatest in low latitudes where the variation in length of day is least Hence in tropical regions there is little *seasonal* difference of temperature, but a great difference between day and night, while in higher latitudes there is relatively little difference between day and night, but greater variation between summer and winter

The second departure from ideal planetary conditions is that dependent upon irregularities in the nature of the earth's surface Roughly, three-quarters of the earth's surface is covered by sea, the remainder (the uncovered surface) we call land To the geographer the distribution of land and sea is of profound importance Such features as the occurrence of most of the land in the Northern Hemisphere, the north to south extension of North America and South America, the east to west extension of Eurasia, *north* of the equator, the east to west extension of North Africa north of the equator, and the north to south extension of South Africa south of the equator, and the roughly rectangular outline of Australia and its situation on the Southern Tropic with east to west extension—all these and corresponding facts about the oceans must be continually borne in mind

The above are the geographical aspects of the problem, the contrasted physical properties of water and of rocks and soils furnish the other factors These physical differences are of fundamental importance In the first place, water, being a liquid, allows of convection currents, and the distribution of heat by means of such currents In the case of the solid land, conduction of heat is the chief means of transmission of heat—together with loss of heat by radiation from the land surface It will be obvious that currents of warm and cold water will influence very considerably the actual climate

in many regions of the world Another point of contrast is in regard to capacity for heat It requires much more heat energy to raise the temperature of a given mass of water than it does to raise the temperature of the same mass of rock-material by a like amount In other words, if the same solar energy is received by land and sea, the rise of temperature of the sea is very slight compared with that of the land During the day, or during the summer as a whole, the sea rises in temperature much more slowly than the neighbouring land Conversely, at night the sea cools much less rapidly than the land Hence during the hottest part of the day the sea is cooler than the land, and during the coldest part of the night the sea is warmer than the neighbouring land The sea therefore exerts a cooling influence during the day and in summer, and a warming influence at night and in winter This is one of the most important climatic facts in nature

To anticipate subsequent studies somewhat, it will follow that in the same latitudes the difference between the January and July temperatures will not be nearly so great in regions near the sea as in places in the middle of the great land masses These contrasts in temperature ranges will be greater in higher than in lower latitudes, other things being equal, for the reasons pointed out earlier in the chapter Some instructive examples may be given to illustrate this point The first one is a comparison of a number of places in Europe in approximately the same latitude, and will serve as an example for cool temperate latitudes

	Cambridge	Utrecht	Berlin	Warsaw
Jan temp .	39°	35°	32°	26°
July ,, . .	64°	65°	66°	66°
Range .	25°	30°	34°	40°

The second example compares places in somewhat

lower latitudes in the interior of the continents with places in similar latitudes but near the ocean

	Santiago [1]	Burgos [1]	Milan	Bucharest.
Jan temp .	47°	42°	33°	26°
July „ . .	67°	71°	76°	74°
Range	20°	29°	43°	48°

These principles will be realised more fully when we proceed to discuss concrete examples of climatic distribution, and when we can with advantage illustrate more fully general principles connected with the different effects of land and water

Latent Heat of Water

We have also to consider another property of water which is of very great importance in respect to climate—that is, the *Latent Heat* of water and of water vapour Whenever a solid substance is liquefied, or when a liquid is converted into a gas without change of composition, there must be an expenditure of heat energy Thus to convert 1 lb of ice at the freezing point (0° C or 32° F) into water at the same temperature needs the expenditure of 80 units of heat—that is, sufficient heat to raise the temperature of 80 lb of water by 1° Again, to convert 1 lb of water at the boiling point into water vapour at the same temperature requires the expenditure of 540 heat units The heat thus expended does not produce rise of temperature, but change of state, and is known as *Latent Heat* This latent heat is, of course, given out again when water vapour changes to the liquid condition or when liquid water changes to solid water (ice or snow)

This part of the subject is so important that it may be explained still further Suppose we begin with a

[1] Corrected for altitude, by adding 1° for each 300 feet of altitude.

mass of ice at, say, 20° F —that is, 12° below the freezing point of water Apply heat to this The temperature of the ice will rise until the melting point (or freezing point) is reached Continue the application of heat There will be no rise of temperature until the ice is melted the heat is being "spent" in changing the physical state, and not in raising the temperature When all the ice is melted, let the heat be still supplied The temperature will again begin to rise and the volume of the water will be changed, at first producing contraction and then after 39° F expansion From this temperature upwards there is continual expansion with increase of temperature, until the boiling point, 212° F, is reached There is now no increase of temperature until all the liquid water has been converted into water vapour If heat be now applied to the water vapour or gas, expansion and rise of temperature occur, just as in the case of other gases

Water differs from other substances in that the latent heat is greater than that of any known substance It is therefore obvious that in the vast amount of water vapour contained in the atmosphere there must be "stored" an immense amount of heat-energy When water vapour "condenses" or becomes liquid, this latent heat-energy is set free and warms the surrounding air and the contiguous land Clearly, then, the atmosphere of a region of great rainfall will contain more heat-energy than would otherwise obtain A vast amount of solar energy is thus transferred by rain-bearing winds from the warmer oceans to the colder lands We shall meet with concrete examples of the application of this and the other principles already studied, but we may here recall the common experience in cool-temperate lands that rain brings warmer weather in winter, and that during very cold weather, country

people often say, "We shall have snow, and it will be warmer" These are every-day expressions of an important principle

The following is a summary of these elementary but fundamental principles.

Climate depends upon—

(*a*) Latitude, because of the angle at which the solar rays strike the earth's surface, and because of the thickness of atmosphere to be penetrated *Theoretical* sun-force at the equinoxes is proportional to the cosine of the latitude

(*b*) A variation is introduced owing to the inclination of the earth, the vertical sun changing its position during a year between the limits of 23½° N and 23½° S The heat equator therefore oscillates between well defined limits on either side of the equator

(*c*) The relation of the atmosphere to sunlight and to heat rays Dry air is transparent and diathermous, but other constituents of the air, especially water vapour, absorb heat rays readily

(*d*) The atmosphere is warmed mainly from the earth's surface by conduction and air-convection, hence temperature diminishes with altitude, the actual average rate of diminution being about 1° for 300 feet

(*e*) The distribution of land and sea introduce another set of factors The great capacity of heat possessed by water causes a much less range of temperature to obtain in the sea, in the atmosphere over and near, and in the land near the sea

(*f*) The great latent heat of water, and especially of water vapour, provides a means for the transference of immense stores of heat-energy from the warmer seas to the colder land surfaces

The application of these principles will be illustrated in the next chapter

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See Chapters XIV , XV.

CHAPTER XIV

CLIMATE AND WEATHER

Some of the elementary facts concerning atmospheric pressure and the chief wind systems were mentioned in Chapter XIII, the subject is now carried somewhat farther. If the earth were a globe uniformly covered

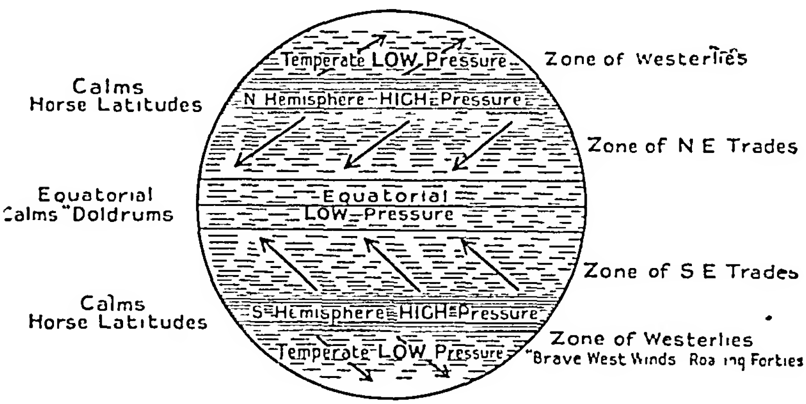

FIG 33 —PRESSURE SYSTEMS OF THE LOWER LAYERS OF THE ATMOSPHERE—IDEAL AVERAGE

with water, and if the axis were at right angles to the plane of the ecliptic, then the pressure zones of the atmosphere would probably be as shown in the diagram Fig 33. These conditions are not realised. Land masses become hotter than the adjoining seas in the same latitude in summer and colder in winter, hence, especially in the Northern Hemisphere, there is considerable modification of the theoretical pressure systems

In the Southern Hemisphere a low-pressure belt passes round the world in cool temperate latitudes, and this is maintained throughout the year, the sub-tropical high-pressure belt is much less interrupted than is the corresponding belt in the Northern Hemisphere

The northern sub-tropical high-pressure belt actually passes round the earth in the northern winter, at which season it is more intensely developed over the great continents, Eurasia and North America On the other hand, in the northern summer the high-pressure belt is

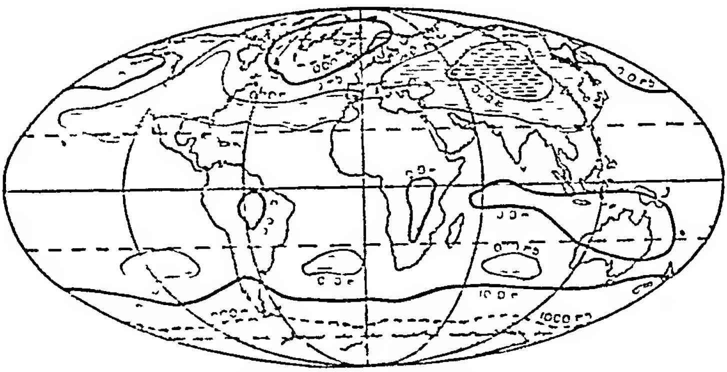

FIG 34—THE PRESSURE SYSTEMS OF THE WORLD—JANUARY

replaced by low-pressure systems over those continents, and there is an alternation of high and low pressure as one proceeds round the world

Polewards of the sub-tropical belt of high pressure there is the cool temperate belt of low pressure, but the alternation of continents and oceans causes similar interference in this zone In the northern summer the northern low-pressure belt is found to pass round the world, in the northern winter it is interrupted over the two great northern continents and there is an alternation of high and low pressures over continents and oceans

respectively These facts are shown on the diagram maps, Figs 34 and 35

It is usual to show seasonal conditions of pressure by the use of maps on which climatic isobars are shown To appreciate the nature and use of isobars, a brief survey of the method of representing atmospheric pressure on maps may be helpful The pressure of the atmosphere is measured by a barometer, and the results were

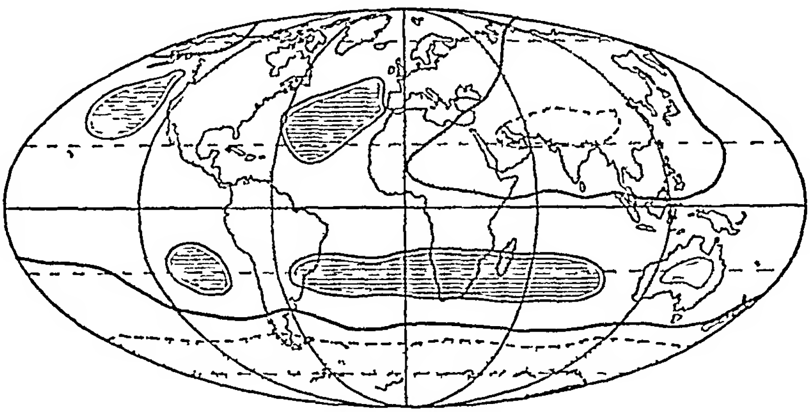

FIG 35—THE PRESSURE SYSTEMS OF THE WORLD—JULY

NOTE —Figs 34 and 35 are drawn on Mollweide's Homolographic Projection, climatic isobars for 1000 mb are shown by broken lines, those over 1000 mb by continuous lines, areas less than 1000 mb are dotted, areas over 1020 mb are shaded, and over 1030 mb more distinctly shaded

formerly expressed in terms of the length of a column of mercury Thus, the standard pressure used for comparison was that of a column of mercury 760 millimetres, or 29 925 inches, in length measured at a definite temperature and definite height with reference to sea-level, and the pressure was spoken of as 760 mm, or 29 925 ins This notation is still widely used, and at the time of writing the British Broadcasting Company give the atmospheric pressure in inches in their

announcements of weather reports Another notation is, however, gradually coming into use, and this demands a brief explanation

The pressure of the atmosphere is a *force*, and its value may be expressed in terms of units of force The unit of force used in the Centimetre-Gramme System is the *dyne*—which may be defined as the force which, acting on a mass of one gram, produces an acceleration of one centimetre per second per second Now the pressure of a column of mercury of length 760 mm (29 925 ins), acting on a square centimetre, is equal to 1,013,230 dynes, which would be a very awkward figure to adopt In its place a force of 1,000,000 dynes per square centimetre is taken as the standard, and this is called a "bar" The working unit of atmospheric pressure used in Meteorology is $\frac{1}{1000}$ of this value and is called a *millibar* A bar (1000 mb) is equal to a pressure of 29 531 inches under the old system , usually it is taken as equivalent to 29 53 inches, or 750 1 mm

Isobars

Suppose the atmospheric pressure to be taken at a number of places at a certain selected time, and let these be corrected to sea-level and plotted on a map, it will now be possible to draw a number of lines through places which have the same barometric pressure at that time , such lines are called *isobars* The familiar weather maps published daily by the Meteorological Office of the Air Ministry, and by some of the daily newspapers, show such isobars for a definite time The pressures are usually given on such maps both in inches and in millibars

There is, however, another kind of isobar which is often drawn on maps , this may be called the *climatic isobar*, and is an expression of the *average* barometric

pressure over a stated period Thus, a climatic isobar of 29 53 ins (1000 mb) for July means that at all places on that line the *average* pressure throughout July has been found to be 29 53 ins (1000 mb) It may be remarked that at any given moment in July of any year the actual barometric pressure may be quite different from the average pressure given on that map The map is a climatic map, not a weather map, and the map shows generalised average values and not values found at any given moment

It will now be possible to understand more clearly the distribution of pressure over the Northern Hemisphere in summer and in winter, and to make profitable comparisons with the distribution of pressure over the Southern Hemisphere where there is much less interference by land masses Some of the main facts of average pressure distribution are shown on the two maps, Figs 34 and 35, to which reference should be made, and especially to the appended note

Seasonal Pressure Systems of Europe and North America

As an example of the application of the above studies the special pressure distributions which more immediately concern the climates of Europe and North America may be briefly mentioned The average pressures in January and July are taken as typical of the winter and summer conditions respectively

Europe—In January there are three well-marked pressure systems which dominate the weather conditions of that month, and which give to Europe the main features of its winter climatic character These are the Azores High Pressure, the Icelandic Low Pressure, and the Eurasian High Pressure, they are shown on

the map, Fig 36 In July the conditions have changed, the Azores system has spread northward and has become relatively more powerful, the Icelandic system is less dominant than in January, but is still important the high pressure over eastern Europe has been replaced by low pressure—a part of the great monsoon low-pressure system of Eurasia

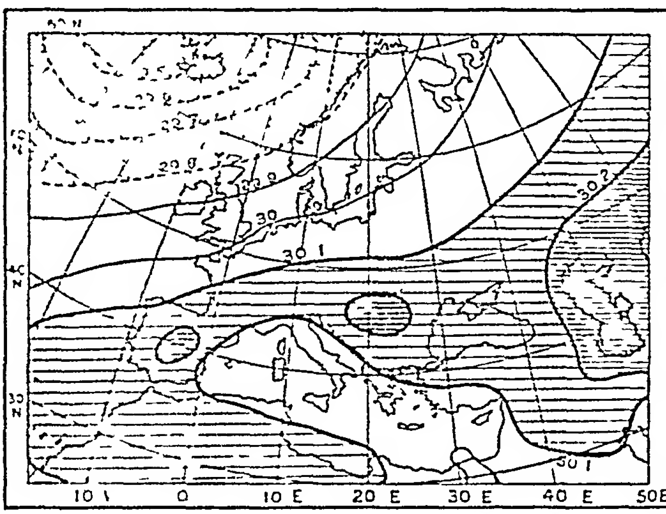

FIG 36 —MAP OF THE PRESSURE SYSTEMS WHICH GOVERN THE CLIMATE OF EUROPE IN WINTER

Chief Isobars for January are shown Map drawn on Bonne's Projection

North America —The climate of North America is governed by two sets of similar oceanic systems east and west of the continent respectively, and a reversible continental one Though the centres of the two high-pressure oceanic systems seem to remain constant in position the systems spread northward in summer and become more pronounced, while at the same time the

oceanic low-pressure systems are weakened In winter the low-pressure systems spread southward and become more pronounced Over the North American continent there is a high-pressure system in January and a low-pressure system in July See map, Fig 37

Barometric Gradient

In representing pressure conditions on weather charts the isobars which have been reduced to sea-level are

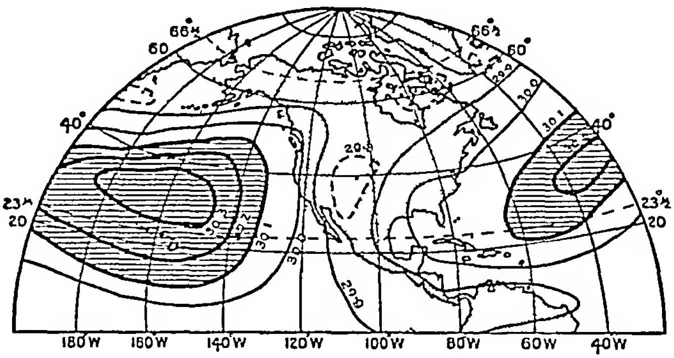

Fig 37—Map of the Pressure Systems which govern the Climate of North America in Summer

Climatic Isobars for July are shown Map drawn on Lambert's Zenithal Equal Area Projection

usually drawn at intervals of two or four millibars, or their equivalents in inches If a series of charts for different times be examined, it will be seen at once that sometimes the isobars are much closer together than at others If the isobars are crowded, it means that there is a rapid fall of pressure from one part of the area to another, and consequently the winds will be strong If the isobars are far apart, the winds will be light By analogy with contour lines drawn on orographical maps, from which the gradients of roads or railways can be found, it is customary to speak of

"barometric gradient" The unit of gradient is usually a difference of pressure of one millibar over an arc of a great circle of 1 degree—that is, 1 mb in 60 nautical miles, or 1 mb in 69 geographical miles, or 1 mb in 111 kilometres A unit gradient gives very light winds, a gradient of 2 gives moderate winds in temperate latitudes

PRESSURE AND WINDS, FERREL'S LAW, BUYS BALLOT'S LAW

If the earth did not rotate winds would blow from regions of high pressure directly to regions of low pressure with a velocity which depended upon the barometric gradient, it is common knowledge that the directions of actual winds do not follow this simple rule

Ferrel, in the latter half of the nineteenth century, showed that winds are always deflected to the right of this theoretical direction in the Northern Hemisphere and to the left in the Southern Hemisphere, this generalisation is generally known as Ferrel's Law Buys Ballot, a Dutch meteorologist, expressed the same truth in somewhat different language, and with reference to actual pressure systems, in 1860 His "law" is thus stated "If you stand with your back to the wind the low pressure will be to your left in the Northern Hemisphere, to your right in the Southern Hemisphere" These "laws" are clearly exemplified in the well-known surface wind systems of the world—the Trade Winds and the Temperate westerlies, and in the temporary winds of cyclones, anticyclones and other pressure systems They do not seem to express fully some of the features of the wind circulation of the upper atmosphere

Local Pressure Systems, and their Associated Weather

The reader should always bear in mind that the pressure systems shown on the diagram, Fig 33, and on the isobaric maps, Figs 34 and 35, represent average pressure conditions, and that there are minor variations of great importance within these world systems Over mid-Eurasia there is always a high-pressure region in midwinter and a low-pressure region in midsummer , but where the continents and oceans meet there is a good deal of local variation For example, the British Isles are in the temperate low-pressure zone, and yet it is quite common in spring to find a local high-pressure system developed over the British Isles and the adjoining seas Some of these local developments will now be discussed

Cyclones [1]—In mid-temperate latitudes, especially over such a region as Western Europe, there is often found a local system with low pressure in the centre, and a more or less concentric increase of pressure outwards If the system is represented in the usual way by isobars, these lines are seen to be more or less circular or elliptical in shape, and to indicate a fairly rapid increase of pressure from the centre outwards The pressure in the middle of the system is often as low as 970 mb , it may be even lower than that in rare cases The barometric gradient is generally 5 mb or more for every degree of arc

These systems vary considerably in area, ranging from as little as 100 miles in width to 2000 miles , a general average width is about 1000 miles They are obviously very shallow systems in comparison with their area, as they cannot extend higher than about 6–7 miles as will be seen later

[1] Usually called " depressions " or " lows " in this country

The winds in the first few hundred metres above ground in a cyclonic system do not blow directly inwards towards the low-pressure centre, their direction is generally more or less parallel to the isobars, with a marked tendency to swirl in towards the centre These

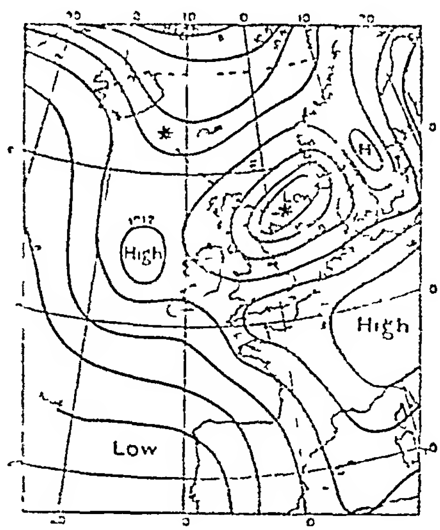

FIG 38.—DIAGRAMMATIC MAP OF A CYCLONE AND ADJOINING SYSTEMS AS DEVELOPED ON MARCH 19TH, 1924

The track of the cyclone (the passage of the eye of the system) for about 18 hours is shown by the broken line between the two stars Isobars for every 2 mb are shown, from 1004–1018 mb

winds of cyclones illustrate the "laws" of Ferrel and Buys Ballot very clearly

Although simplified so far as absence of friction is concerned there are at higher levels within the system somewhat complicated conditions which are still the subject of investigation, it is known that there are currents of air rising obliquely, and that frequently

cold currents from the north or north-east pass under and lift up warmer currents from the south or south-west The air in the middle of a cyclone clearly does not ascend directly as up a warm chimney, as was at one time supposed to be the case

A cyclonic system in temperate latitudes moves along a well-defined path at a rate which is very variable for different cyclones The velocity of translation is usually greater in winter than in summer, and cyclones of great intensity (those with steep gradients) travel faster than shallow ones The average velocity of North American cyclones is estimated at about 26 miles an hour, that of Japanese cyclones at 24 miles an hour, and that of European cyclones at 16 miles an hour

Very rarely do any of the numerous cyclones of North America cross to Europe, for, on leaving the American coast, they generally travel northward and north-eastward and break up in the Polar regions The frequent cyclones of Western Europe originate over the North Atlantic and generally travel eastward or north-eastward, their paths avoiding the high lands of Middle Europe and Scandinavia for the most part In summer, when the Azores high-pressure system spreads northward, the cyclonic tracks seem to be forced nearer to the Icelandic low-pressure region Many meteorologists have attempted to make charts of cyclonic tracks in Western Europe, one of the most helpful is that of Geddes in his *Meteorology*, where he shows the tracks of the cyclones for the year 1918, and gives the numbers for each direction

The "path" of a cyclone is by definition the line followed by the centre of the system as it travels along If a line is drawn through the centre at right angles to the path, this is called the "trough" of the cyclone The trough and the line of the path by their inter-

section mark out the four quadrants, which are known as front right (south-east), front left, back right, and back left respectively In the front right or south-eastern quadrant the winds are usually south and south-west in Britain, the atmosphere is "muggy" and oppressive, and there is much cloud and rain In the rear of a cyclone the winds are more west and north-west, there are frequent breaks in the clouds, showers

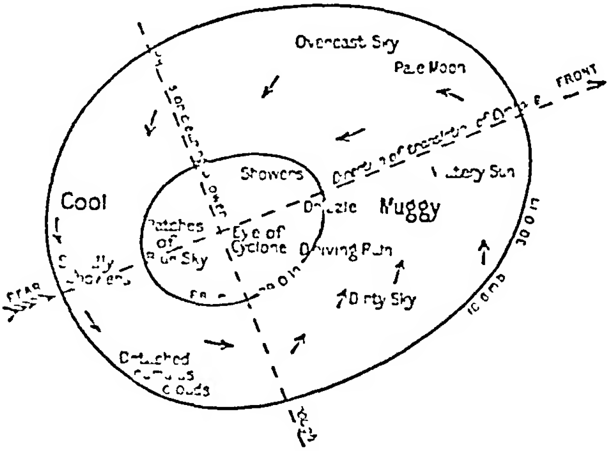

FIG 30.—"WEATHER" IN A WEST EUROPEAN CYCLONE—GENERALISED AND SIMPLIFIED

alternate with periods of blue sky, and the atmosphere has a bracing effect The front left and back left quadrants of a cyclone are usually decidedly colder than the other two quadrants In the case of cyclones passing across the British Isles from the Atlantic, the front right or south-eastern quadrant is, as a rule, much warmer than the others as can readily be understood from the direction of the winds

The above brief description applies to cyclones of

mid-temperate and cool-temperate latitudes Tropical cyclones are much more intense as a rule—that is, their barometric gradients are steeper, and their winds are consequently stronger, but the systems themselves do not move with any greater velocity These tropical cyclones are usually not more than 500 miles in width, and within this distance there may be a fall of pressure from 1020 mb at the periphery to 960 mb at the centre —that is, the barometric gradient is about 16 mb per degree of arc Tropical cyclones are commonest on the western sides of the oceans, and over the seas on both sides of India They originate over the sea and soon break up or become less intense, especially if their path takes them over the land

Anticyclones [1]—These are well-defined systems with pressure high in the centre and diminishing outwards in a more or less concentric fashion Their isobaric representation shows circles or ellipses as in cyclones If the isobars are drawn for the same intervals of pressure as in cyclones, they are seen to be farther apart as a rule—that is, the barometric gradient is not so steep In a width of some 2000 miles the pressure usually varies from about 1030–1035 mb. in the centre to 1000 mb at the edge of the system—that is, the barometric gradient is about 2–2 7 mb per degree of arc Winds are therefore much lighter, as a rule, and more variable in direction, there is seldom much rain, but banks of cloud at about 3000 feet, or 1 kilometre, and ground fog are common in many anticyclones over the British region On the whole the weather in winter in temperate regions tends to be clear and frosty, in summer, sunny with a good deal of morning mist

Anticyclones seldom travel in well-defined paths, and they frequently remain fairly steady for days or even

[1] Sometimes called "highs" in this country

weeks They do not seem to be directly associated with or complementary to the cyclones of similar latitudes, and they are not nearly so frequent in occurrence

Before leaving the subject of anticyclones it should

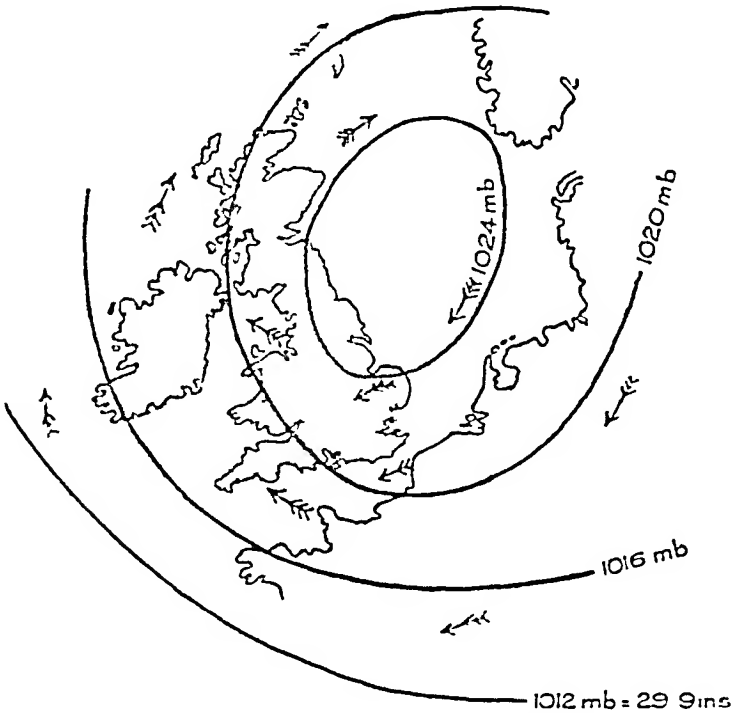

Fig. 40 — Anticyclonic Pressure System

be noted that some writers describe the winter high-pressure system over Eurasia as an anticyclone This is an extension of the use of the word as originally suggested by Galton, and in the writer's judgment it would be better to speak of this particular system as the continental high-pressure system over Eurasia and to

reserve the name Anticyclone for the local and temporary weather systems, as seems to have been the original intention

Other Pressure Systems —There are many other possible local distributions of pressure, some of which receive definite names from the shape and arrangement of the isobars The high-pressure *wedge* is a V-shaped arrangement of isobars between two cyclones The *col* is a saddle-shaped arrangement of isobars lying between two high-pressure and two low-pressure systems grouped alternately *Secondary* depressions (local systems of low pressure) often lie within the periphery of great cyclonic areas , they are usually associated with stormy weather *Straight* isobars are frequently seen occupying a wide area between a high-pressure and a low-pressure system , variable weather is generally associated with such a system

In the ordinary weather maps and forecasts issued by the Meteorological Office of the Air Ministry, continual reference is made to depressions, anticyclones, secondaries, and other local pressure systems, and the graphical representation of these systems is very important

Ekholm, a Swedish meteorologist, has suggested that the rate of change of pressure should be represented rather than the actual pressures at the time, and he therefore draws on his weather charts a series of lines through places which show the same amount of change in a given time , such lines are called *isallobars* The reader may notice small inset maps showing isallobars on the Daily Weather Charts already mentioned

The Free Atmosphere

In the discussion of Ferrel's and Buys Ballot's laws mention was made of the winds of the upper atmosphere.

Modern investigation is showing that many things which happen near the earth's surface are either influenced by or directly dependent upon the upper or free atmosphere, hence it is necessary to give some account of the findings of this new and interesting branch of Meteorology

By the Free Atmosphere is meant that part of the earth's gaseous envelope which is beyond and uninfluenced by the irregularities of the earth's solid surface Very little was known about this upper air until quite recently The general laws of the rate of fall in temperature and pressure with increasing height had been established during the middle part of the nineteenth century, and it seems to have been assumed that the same laws would hold in the unexplored upper air as had been established in the first 15,000 feet, or 4–6 kilometres, or thereabouts, with which Alpine students and physicists had made the scientific world familiar Borrowing a simile from exploration of the deep ocean, it may be said that soundings began to penetrate deeper and deeper into the unknown upper air in the latter half of the century Glaisher and Coxwell ascended in a balloon to about 33,000–34,000 feet in 1862, but the exact height was not known as both observers had become unconscious Captive balloons with self-recording barometers and thermometers were increasingly used after that time, and by the end of the century there had been pressed into the service kites, " ballons sondes " (sounding balloons), pilot balloons, and aeroplanes, in addition to the manned balloons and captive balloons already mentioned

Aeroplanes have proved of great use in adding to our knowledge of the lowest 3–4 miles of the air, and occasionally beyond that, for greater heights sounding balloons and kites fitted with special self-recording instruments are now widely used The instruments

sent up with the kites make graphs of the readings of the barometer, the thermometer, the hygrometer, and the anemometer Sounding balloons are made of rubber, and are about 1 to 2 metres in diameter, they usually carry the first three instruments mentioned above To ensure that as many groups of results as possible may be obtained and recorded, a reward of 5s is offered to any one who picks up the fallen framework and its meteorograph and informs the Meteorological Office of his discovery Pilot balloons of 18–20 inches in diameter are used for determination of wind direction and velocity, these balloons are comparatively cheap and easily sent up, they reach such heights as 3, 4, 5 or more kilometres, and their movements may be watched by skilled observers using telescopic theodolites

By the use of these special instruments and new methods a new world of knowledge has been opened up, especially since the discovery by Teisserenc de Bort in 1899 of a layer or stratum in the atmosphere beyond which there is no fall of temperature with increasing height The average fall of temperature is usually stated to be 1° F for every 300 feet of ascent This is broadly true in the lower layers of the atmosphere, but the fall does not continue beyond the layer which de Bort called the Isothermal Layer This stratum is reached at about 11 kilometres, or 7 miles, above sea-level in cool temperate regions

After de Bort's discovery the existence of this critical layer was proved in many regions and it is now possible to give a tentative summary of results In the Polar regions the Isothermal Layer occurs at about 8 kilometres, in the latitude of London at about 10 5 kilometres, in Southern Europe at about 11 2 kilometres, and near the equator at about 16–17 kilometres Below this layer the average lapse rate of temperature holds

and the lower atmosphere in which this fall takes place is now called the Troposphere. Beyond the stratum of no change, known as the Tropopause, is the Stratosphere in which there is no further fall of temperature and no convection currents exist.

The temperature at 14 kilometres (nearly 9 miles) over five regions in Europe has been found to vary from 218° to 223° Absolute—that is, from −55° C. to −50° C., being higher in Northern Europe than in Southern Europe. The pressure seems to become almost uniform all over the world at about 20 kilometres (12½ miles) above the earth's surface, the average for the year being about 55 mb., compared with a variable pressure at sea-level ranging from 960 mb. to 1040 mb. The changes of pressure beyond 20 kilometres are as yet little known, but it has been calculated that at a height of 120 kilometres (75 miles) the pressure will be about 0.0008 mb.

The height above which there is no change of temperature varies with the seasons, and is lower over cyclones and higher over anticyclones. Another important discovery is that in the critical layer the movements of the air are mainly in a horizontal direction—that is, there seems to be little passage of air from the troposphere below to the stratosphere above, or *vice versa*. The general direction of this horizontal movement is from the east in the tropics and from the west in extra-tropical regions.

Within the troposphere convection currents are, of course, common, and the *relative* composition of the air remains practically constant throughout. There is still much to be learned regarding the composition of the stratosphere, but it is almost certain that beyond the critical layer there is no moisture and probably no carbon dioxide. The constituents of the upper atmosphere beyond about 100 kilometres are variously given

by different authorities as predominantly hydrogen, or helium, or geocoronium with hydrogen respectively

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CHAPTER XV

SOME CONCRETE STUDIES IN CLIMATE

It may be advisable now to take certain well-marked climatic types and to study them in more detail The region of tropical calms, where the trade winds pass gradually into the ascending air currents of the low-pressure equatorial zone, suggests itself as the first type, and from this it will be convenient to pass to other types, some of them modifications in the equatorial regions themselves, and afterwards to higher latitudes, noting some of the changes in climatic character

The Equatorial, Hot, Rainy Belt.—This is essentially a belt of calms, and there is an absence of regular winds The sun shines overhead,[1] or at a very high altitude, all the year round, the earth's surface becomes intensely hot during the day, and the air is heated by the usual methods of conduction and convection currents The warm air contains a great deal of moisture, and as it rises and is cooled by expansion, rain falls in great quantities Thus the belt is hot and rainy, and some of the heaviest rainfalls of the world are recorded There may be two very wet and two less wet seasons in the year, owing to the moving of the heat equator, but on the whole there is no really dry season, it is essentially a zone of continual rains There is little seasonal difference of temperature, a range of very few degrees being all that is recorded in most parts,

[1] At noon.

except in the middle of the continents and on equatorial plateaux On the other hand, the daily range is considerable, the extremely hot day being succeeded by a relatively cool night

As the land becomes much hotter than the neighbouring sea during the day, warm air will rise and cooler air come in from the sea, thus land and sea breezes may be a regular feature, land or offshore breezes at night, sea breezes during the day

The typical conditions of heavy rain, low seasonal range of temperature, are well developed near the equator in the Atlantic and Pacific Oceans, in the Valley of the Amazon, the Basin of the Congo, the northern lowlands of the Guinea Coast, and the lowlands of equatorial Malaysia The typical development is modified on the highlands of Ecuador, the highlands of equatorial East Africa, and the mountains of Malaysia, including New Guinea In Ecuador, which may be taken as an easily understood modification, there are well developed three or four ascending climatic zones, *tierra caliente* or hot belt, *tierra templada* or temperate belt, *tierra fria* or cool belt, and *tierra helida* or snow belt

The plateaux between the equatorial Andes have a warm-temperate or cool-temperate climate, according to elevation, Quito, the capital of Ecuador, at a height of 8000 feet, has almost "perpetual spring," owing to its elevation and its position on the equator The equatorial position is responsible for the low seasonal range, the altitude, for the temperate average [1]

The Hot Regions of Summer Rains.—Outside the equatorial zone of rains all the year round there are on both sides of the equator narrow belts where "the rains follow the sun" The rains are therefore essentially abundant

[1] See pages 321–326 for examples of most of the climatic types

summer rains, and a well-marked dry season of five or six months intervenes In these belts the difference of temperature between day and night, and especially between the hot and cold seasons, is more marked

This climatic type occurs close to the hot wet belt, and is well developed in Nigeria, the Upper Guinea lands, the southern Congo Basin, the north coast of South America, and northern Australia In the Congo Basin the rainy seasons of the northern and southern tributaries occur in alternate seasons, the same happens in the Amazon basin

The Trade-Wind Type.—Beyond the zones of summer rains on each side of the equator, are the zones where the trade winds blow steadily These winds blow from cooler to warmer regions, and the capacity of the air for moisture is being increased, hence if the trade winds blow across the land they are dry winds, absorbing moisture from the land surface As the trade winds blow from north-east north of the equator and from south-east south of the equator, there will be a desert belt on each side of the equator, on or about the latitude of the tropics, wherever the extent of the continent allows of it These typical hot deserts are found in North Africa, South Africa, Australia, south-western Asia, Mexico, and southern United States, and South America. In these deserts the daily range of temperature is very great, and the seasonal range is much greater than it is nearer the equator, the hottest summers known are found in these belts On temperature maps showing isotherms, the familiar closed areas of over 90° F are mostly in these desert areas, for an example, see a temperature map of Africa.

This desert condition is modified when the trade winds blow across an ocean and afterwards rise over an eastern side of a continent. Then these eastern con-

tinental sides of the trade-wind zone may receive fairly abundant rains The south-east of Africa, including Madagascar, the east and south-east of Australia the south-east coast of Brazil, the Guiana coast of South America, and the West Indies and Central America receive trade-wind rains

The Mediterranean Type of Climate—Passing still farther from the equator we come to that type of climate which is deservedly called the Mediterranean type, because that particular region shows it normally developed The essentials are dry, warm summers and wet, mild winters As the sun in its northern journey reaches the limit of the tropic line, the trade-wind belt, of course, swings northward and extends to between 35° and 40° north The Mediterranean and northern Africa are now within trade-wind influences, and the summer is therefore dry and warm During the winter the sun migrates southward to its southerly tropic limit of 23½° South The trade-wind belt swings southward, and its northerly limit is now south of the Mediterranean This region is, therefore, within the limits and under the influence of the westerly winds, the so-called anti-trades These bring rain from the North Atlantic Ocean, and so the Mediterranean receives westerly rains This type of climate may be summed up as follows dry, warm summers, mild and rainy winters It occurs in similar latitudes on the westerly side of all the other continents—middle California, middle Chile, the extreme south-west and south of Africa, south-west and south Australia

The China Type—On the opposite side of the great continents there is a different type, the rains come in summer and the winters are dry The winter temperature is much lower than in the regions of Mediterranean type Mukden in Manchuria, for

example, in latitude 40°, corresponds in position with the Mediterranean It has summer rains and dry winters, its average January temperature is 8° and its average July temperature 76°

Korea, in latitude 39°, has summer rains, with an average January temperature of about 26° and a July temperature of 74° Nagasaki, which is in latitude 32°, has a January temperature of 41° and a July temperature of 80° This is the Eastern or China warm temperate type, with relatively cold winters and warm summers The rivers of the north of China, though in the same latitude as Spain, are frozen in winter Snow falls nearer the equator in China than anywhere else in the world, the winters are relatively so cold Somewhat similar conditions hold in the eastern United States, except that Florida and the Gulf regions are nearer the equator than the places quoted in Eastern Asia, and the winters are not nearly so cold Natal and the east of Australia south of about latitude 30° south, belong to a modified China type, in both cases having milder winters, however.

The British Type of Climate, or Western Cool-Temperate Type.—Passing from the warm-temperate to the cool-temperate zone, we meet with another type Approximately lat 45° may be taken as the arbitrary division between warm-temperate and cool temperate, though it is notorious that there is sometimes a difference of quite 10° of latitude between the two sides of a continent Broadly speaking, the warm temperate zone lies between 23½° and 45°, and the cool temperate zone between 45° and 66½° The trade-wind belt occupies much of the warm-temperate zone, especially in summer

The cool temperate type is well seen in the British Isles, most of France and Continental Europe, north

of the Alps, and as far east as Bohemia The part of Scandinavia south of the Arctic Circle is also of this type, excepting that the high elevation of much of it causes a modification of conditions, and gives to its plateaux an arctic climate The winds are westerly for the most part, and rains therefore fall nearly all the year round, more especially in late summer, autumn, and winter The range of temperature is nowhere very great The climate may be summed up as rainy at all seasons, with cool winters and moderately warm summers

British Columbia, with its island fringe, southern Chile, South Island, New Zealand, and Tasmania have this westerly-winds type of climate

The Laurentian Type—On the eastern sides of the continents in approximately the same latitude there is a somewhat different climate, the winters are a good deal colder, and the summers are very slightly warmer Rainfall is not nearly so abundant This has been called the Laurentian type, because its typical development is in the lands round the mouth of the St Lawrence Northern Manchuria and the extreme south-eastern corner of Argentina are of the Laurentian type No part of Africa or Australasia comes within it The rivers are ice-bound in winter and most of the harbours are closed The following are typical examples of this Laurentian climate

	Lat	Jan Temp	July Temp
Nikolayevsk (at mouth of Amur River)	50°	−9°	61°
Vladivostock in Eastern Manchuria	43°	−4°	66°
Halifax in Nova Scotia .	44°	22°	65°

The Tundra Type of Climate—Still farther from the equator, and within the Arctic Circle, we come to the last type to be considered,—the Tundra or Arctic Lowland type The year here consists of two seasons,

a long, severe winter with very little daylight, and a short summer with continuous or almost continuous daylight, but of low intensity The atmosphere is cold and the pressure is usually rather high There is not much rain and it may be called the cold-desert type Herschel Island, at the mouth of the Mackenzie River may be taken as a good example

Herschel Island, lat 69° N Rainfall very little January temperature, -20°, July temp, 44°, range 64°

The above are the chief climatic types It will be noticed that every one is well represented in the Old World, in the Northern Hemisphere, and the development of each type is so distinct that it may be well studied there From the equatorial basin of the Congo to the arctic tundra of Northern Russia, there is every western modification, while the Chinese and Laurentian types are represented on the eastern side of Asia

We have thus far dealt with the normal climates of the earth's surface first of all as produced by the incidence of the sun's rays on the earth's surface, and the rotation of the earth, and as modified in the most obvious and elementary manner by the relation of the continents to the oceans on their western or eastern sides These climatic types are the direct results of the planetary circulation, modified by relations of continents to oceans, the Mediterranean as distinct from the Chinese, the British as contrasted with the Laurentian, for example Now we pass to that most remarkable modification known as the "Monsoon" climate, where for nearly half the year the normal planetary circulation is absolutely reversed, and unique conditions are set up

The Monsoon Climate.—The typical development of this climate is in south-eastern Asia and the adjacent oceans The great Asiatic land mass has an east to west extension, lies wholly north of the equator, and extends

north to within the Arctic Circle Parallel to the greatest extent of the continent lies a great ocean, the continent and ocean lying on either side of the equator Consider first the northern summer, when the sun is north of the equator and at its farthest northward extension is vertical over the Tropic of Cancer on 21st June The continent is now warmed to a temperature much higher than that of the Indian Ocean, the warmest part of the continent, having an average *sea-level* temperature in July of over 90° North Persia and Mesopotamia, a large part of Arabia and some parts of north-west India, have then very high summer temperatures It is obvious that there will be a low-pressure area in that region, and as a matter of fact a vast area has an average pressure below 29 5 inches At the same time the pressure over the Indian Ocean is above 29 9 for the most part Air will therefore flow from the Indian Ocean high-pressure area to the continental low-pressure area Owing to the influence of the earth's rotation this produces an inflow of air from south-west to north-east over southern India, from south to north over Siam, and from south-east to north-west over China The winds blow *into* the continent all along the southern and eastern border from about May to October, these are the summer monsoons of southern and eastern Asia, it is obvious they will generally be rain-bearing winds, and it is quite easy to see why south-eastern Asia has such a high summer rainfall, especially where the ground rises abruptly and alters the direction of the rain-bearing winds, as, for example, in the lands to the north of the Bay of Bengal, where the highest known rainfall in the world has been recorded In the northern winter the sun travels south of the equator, and is overhead at the Tropic of Capricorn on 21st December, the continent now cools down quickly and the surface of Asia

becomes much colder than the surface of the Indian Ocean A very large area in the middle of Asia has an average January temperature of $-30°$ or below, while at the same time the air over the Indian Ocean is at $70°$ or over There is thus a great difference between the continent and the ocean Now the high-pressure area is over the continent, a large part of its atmosphere being over 30 5 inches pressure, while the pressure over the Indian Ocean is below 29 8 inches The winds therefore blow from the continental high-pressure area to the oceanic low-pressure area, though again, owing to the earth's rotation, they do not blow *directly* from the high-pressure area to the low-pressure area The winds blow outwards from the continent on the eastern side, and on the southern side in India and Baluchistan distinctly from the north-east These winds blow roughly from November to March or April and are as a rule dry winds, and the period of their predominance is the "dry winter" of southern and eastern Asia These seasonal winds are the "Monsoons"

In no other part of the world are monsoon conditions so well established, though they are felt in north-eastern Australia, in the Guinea coast lands, in north-eastern Africa, and in the south-eastern parts of the United States, where planetary conditions are overridden, and wet summer winds supplant the usual trade winds to some extent

Regional Studies in Climate

To understand the principles of climate more thoroughly, it is advisable to study the climates of certain well known regions in some detail The following are selected as types The British Isles, the Mediterranean, North America, India, Australasia, South Africa The study of the climate of these regions will illustrate general principles Some amount of repetition is

inevitable The student should constantly refer to the climatic maps of a good modern atlas

The British Isles—These islands lie in the region of prevalent westerly winds To the casual observer the winds of the British Isles may seem very variable, but when they are tabulated year after year it is evident that on the great majority of days the wind blows from west, south-west, or north-west There are north-east winds on a considerable number of days, but these winds are by no means so common as the westerlies

As the commonest winds blow from over a warm ocean, they will bring to the British Isles a considerable amount of moisture Meeting the western hilly regions as they do athwart their direction, there is heavy precipitation on the westerly side, with a general diminution towards the east, though, of course, there are many minor variations An average annual rainfall of over 80 inches occurs in the south-west of Ireland, in South Wales, in North Wales, in the Lake District salient, and in the north-west Highlands of Scotland Some parts of the low lands in the south-east receive less than 25 inches per annum Very sharp "rain-shadows" are seen in the Wirral Peninsula, in the "North-eastern Plain," in the Somersetshire lowlands, all cases where lowlands lie well under the lee of moorlands on which the rainfall is relatively heavy

The distribution of the rainfall throughout the year is approximately as follows, in percentages

	Winter	Spring	Summer	Autumn
Ireland	28	21	24	27
West of England	28	19	24	29
East of England	23	19	28	30

The all-the-year distribution of the rainfall is obvious Spring is the driest time on the whole

With respect to temperature it has already been

pointed out that the average for the year is higher than that of any region in the same latitude The distribution of the isotherms is worth noting In winter, as may be expected, the temperature diminishes towards the east, and the east of the British Isles is the cold region, while the oceanic side is warmer The January isotherm of 40° runs from the Orkneys, almost through Cape Wrath, along the west of Scotland, the north west of England, along the borders of England and Wales, and across Wessex to the Isle of Wight Some portions of eastern Great Britain have an average of less than 38°, and some parts of the extreme west of Ireland have an average of over 42° in January The 40° isotherm may be taken as the average for the British Isles for the coldest month In summer the isotherms run more nearly east and west, and thus the normal arrangement holds,—the north being cooler than the south The 60° isotherm for July may be taken as the average, and it extends across the middle of the British Isles from east to west, with a distinct bend southward in the Irish Sea Only a small part of the British Isles in the south-east has a July average temperature over 64°, and there is only the slightest portion with an average for July below 56° Thus, if 40° be taken as the average of the coldest month and 60° as the average of the warmest month, we may take 50° as the approximate average temperature for the whole of the British Isles for the year The student may profitably compare these constants—40°, 50°, 60°—with the constants for, say the North-German plain, or the middle of Russia in similar latitudes

	British Isles	Berlin.	Moscow
Coldest month (January)	40°	32°	12°
Warmest month (July)	60°	66°	66°
Computed average for year	50°	48°	41°

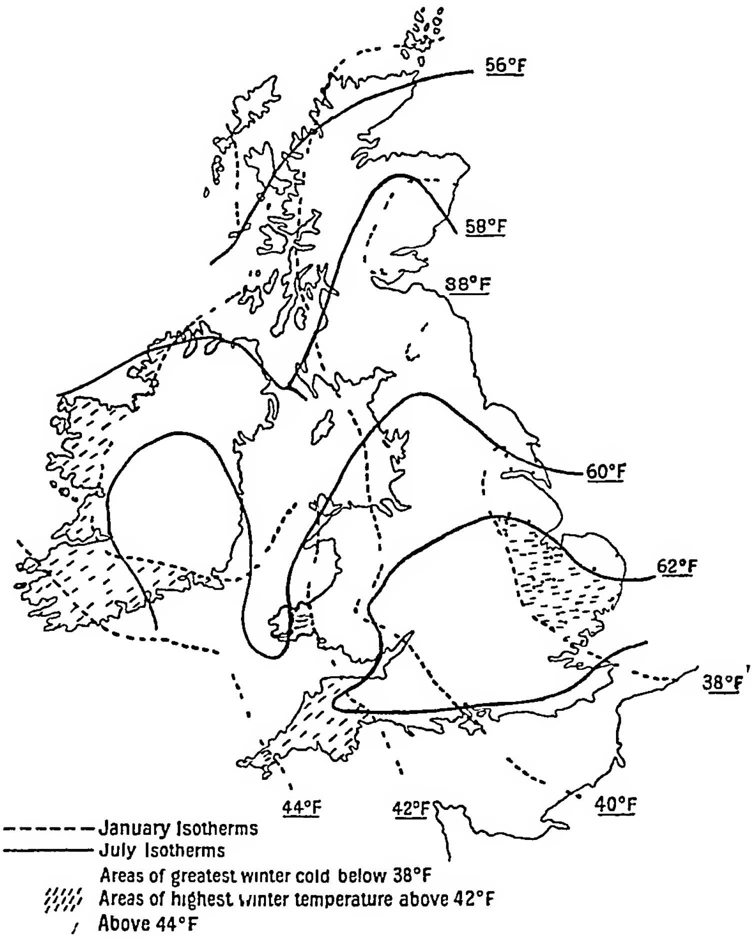

FIG 41 —THE DISTRIBUTION OF TEMPERATURE, AT *SEA-LEVEL*, IN THE BRITISH ISLES

Note the region in the Eastern Midlands with January temperature, *below* 38° F , and July temperature *above* 62° F This is the region of greatest extremes in Britain, the range being *over* 24° F There is a very small region in the north west of Ireland where the January temperature is *above* 42° F , and the July temperature is *below* 58° F , the range being *below* 16° F

The dominant characteristics of the British climate are therefore

(1) Predominance of westerly winds
(2) Rain all the year round, with the least amount in late spring
(3) The west is the wetter side
(4) The west is warmer than the east in winter
(5) The range of temperature is low considering the latitude, and the mean temperature is relatively high

Europe in General.—With the exception of a small part of northern Scandinavia and the far north of Russia in Europe this continent lies wholly in the intermediate or so-called north temperate zone It extends from 35° to 71° north latitude, so that if we accept 45° N as an arbitrary dividing line between the warmer and the cooler sub-divisions of this zone we may see from the map that rather more of Europe is in the warm-temperate half than in the cooler half Europe is a peninsular extension of the vast land-mass of Eurasia, having the deep, warm Atlantic Ocean on the whole of its outer western border, the warm, deep Mediterranean Sea on its southern, and the shallow continental seas on its northern and north-western, side It is important to bear in mind the shallowness of the White Sea, the Baltic Sea, the North Sea, and the narrow seas of the British Isles, all these are rarely more than 300 feet deep, and they are really parts of the continental plain covered with but a shallow sea Another important factor is that the North Atlantic Ocean on western Europe has, allowing for its latitude, the highest surface temperature of the oceans

It is significant that Europe is a *western* extension and not an eastward extension of the great continental mass of which it is a part, for this means that it lies

in the track of the prevailing south-westerly winds of the northern hemisphere's intermediate latitudes When we remember, too, that Europe is more penetrated by seas than is any other continent we can readily understand some important features of its climate North-western Europe has the warmest climate in the world for its latitude, and its Atlantic harbours are seldom troubled by ice The warm south-westerly winds, the rains from the west, and the warm surface drifts from the Atlantic keep open all the year some of the outer harbours of Scandinavia even within the Arctic Circle Westerly or Atlantic influences dominate western Europe, especially in winter, and even penetrate as far eastward as mid-Russia, where Moscow receives 21 inches of rain per year on an average Similar influences penetrate the Mediterranean region so far east as the Southern Caucasus and even Mesopotamia, and the northern Levant, Syria, and Palestine receive Atlantic-fed rains in the winter

Another important feature of Europe should be appreciated, and that is the orientation of its orographical features, which have on the whole a west to east extension We may distinguish four structural units which have this west to east direction—the Mediterranean Sea, the Alpine system on the whole, the great European Plain, and the old mountains of the British Isles and Scandinavia The reader may profitably compare Europe with North America in similar latitudes in this respect

Three chief climatic types may be recognised in Europe.

(*a*) The north-western or Atlantic type
(*b*) The Russian or mid-continental type
(*c*) The Mediterranean type

(*a*) The north-western type is essentially equable in

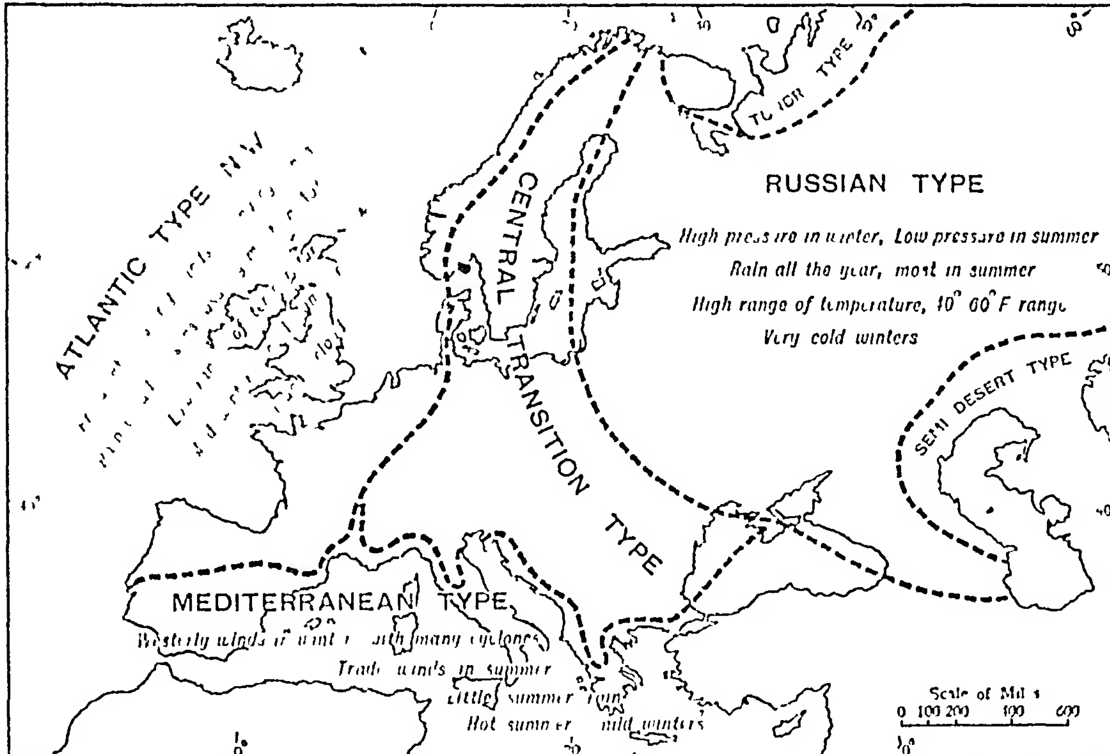

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FIG 12 —THE CLIMATIC PROVINCES OF EUROPE

temperature, both daily and seasonally, with a high average temperature for its latitude, the winds are mostly westerly, and there is rain at all seasons Cyclones are numerous, and there is much cloud The weather is variable, but the changes are numerous and rapid rather than great, really very hot weather and very cold weather are almost unknown, and long spells of continued rain or of continued fine weather are not common

This Atlantic type is well represented by the British climate, which has been described already, the wider type extends from the North Cape to the mid-west of the Iberian peninsula, with the same general characters There are, of course, differences due to latitude, one of the most important of which is the diminution in the proportion of summer rain noticed as one proceeds southward on the Atlantic margin of the continent Santiago, in north-west Spain, receives only 10 per cent of its rather heavy rainfall in the three summer months—June, July, and August, Lisbon, still farther south, receives only 4 per cent of its rain in the same three months, and Gibraltar is decidedly Mediterranean, and not in the north-western climatic province at all, receiving about 1½ per cent of its annual rainfall in the three months mentioned

(*b*) Most of Russia has a typically extreme climate of continental type This part of Europe is climatically allied to Asia, and Kendrew treats Russia in Europe along with Asiatic Russia [1] The usual seasonal changes of pressure of continents in intermediate latitudes is experienced, high pressure in winter and low pressure in summer, except that a summer wedge of relatively high pressure extends from peninsular Europe into mid-Russia The rainfall is decidedly a summer one,

[1] See Kendrew, *The Climates of the Continent*

Moscow, for example, receiving in the six months April to September 13.3 inches of its annual average of 21 inches, or 63 per cent of summer. Warsaw also receives 63 per cent and Kiev 61 per cent in the same six months. Much of this summer rain comes in the usual mid continental form of thunderstorm rain, and the moderate amount of fall is quite compatible with a high percentage of sunshine.

The temperature range is extreme, very greatly so in contrast with similar latitudes in western Europe; the winters are very cold, and the summers are hot. The average daily temperature rises very rapidly in April, and falls with corresponding rapidity in October. A useful study is to compare two places in nearly the same latitude in this respect—London with Orenburg in eastern Russia. At London the average daily temperature rises from 45° F. to 50° F., that is a rise during the month of 5° F.; at Orenburg the rise during the month is 21° F., that is from 27° F. to 48° F. The seasonal ranges of temperature of the two places may be compared usefully as illustrating the two types.

	January	July	Range
London	38½° F.	62½° F.	24° F.
Orenburg	3½° F.	71° F.	67½° F.

(c) The Mediterranean climate is treated separately in the following section (p. 301).

Central Europe is clearly transitional in various stages between the three chief types. While the winds are westerly and south-westerly more than from other directions, they are not so persistent as in the Atlantic province, and cyclones are not nearly so common. On the other hand, anticyclonic conditions are commoner, especially in winter. Very often, while the British Isles are experiencing a succession of westerly winds, warm rains, and warm weather, the European Plain is

under the influence of an anticyclone, and the weather is calm, clear, and cold, especially at nights On the whole the rainfall comes all the year round with a tendency towards a decided summer maximum , and there is no pronounced dry season East of about 10° longitude the rivers are almost invariably frozen for a time in the winter, the length of the closed period increasing towards the east Icebreakers have to be used on the Elbe almost every winter, the Oder is usually frozen for two to three months, and the Vistula for about a month longer Even the lower Danube, although so far south, is generally closed for over a month, and in more severe winters for a longer period

There are two quite minor developments of other climatic types in Europe In the extreme north of Finland and Russia the Arctic lowland or tundra type of climate is experienced The precipitation is slight, the winters are very cold, the summers are cool, and the annual temperature range is 50°–60° F A January average temperature of 0° F , and a July average temperature of 55° F would correctly represent the region The surface of the ground is frozen hard for most of the year, the upper three feet or so thawing for about three months , at a depth of four or five feet the subsoil is permanently frozen The rivers are closed by ice for at least six months on an average

In the extreme south-east of Russia the climate passes into the semi-desert type The rainfall is about 4 to 6 inches a year, and is irregular and uncertain The range of temperature, 60° F or more, is high for such intermediate latitudes as 45°–50° N Precipitation is so low and evaporation so high that there is no oceanic drainage, and the Caspian basin is not filled to normal sea-level with water , in other words, all the northern shores of the Caspian Sea are below sea-level

The Mediterranean Region.—In this region we include the Mediterranean itself, the southern peninsulas of Europe, the extreme south of France, Asia Minor and the Levant lands, and Africa north of the Great Desert. The peculiar features of Mediterranean climates have already been worked out in considering the general planetary circulation. These conditions are dry, warm summers, and mild, rainy winters, with, of course, local variations dependent upon local conditions. This type is characteristic of latitudes about 35°–40° on the west side of the continents and it is more or less completely developed in the five continents where it is possible.—Europe, North America, South America, South Africa, South Australia.

In the Mediterranean type region, the long comparatively narrow, but deep inland sea, with the branch seas the Adriatic, the Ægean, and the Black Sea, cause the peculiar Mediterranean conditions to extend far into the continents. So far east as western Persia the influence of Mediterranean conditions is clearly felt, for the limited rains there are winter rains brought by westerly winds. The distribution of rainfall at Malta may be taken as an example of well-developed Mediterranean conditions. The annual rainfall of about 21 inches is distributed approximately as follows —10 inches winter, 3 inches spring, 1 inch summer, and 7 inches autumn.

The most remarkable local modification in the Mediterranean region itself is the excessive rainfall of the Karst or Dalmatian coast lands on the east of the Adriatic. A maximum annual rainfall of about 200 inches is recorded in the Dalmatian village of Cherkvitce. The relatively warm winds of the Adriatic are forced to ascend rapidly the abrupt mountain wall of the Dinaric Alps, and rapid condensation and exceptionally heavy

rain follows Some rain falls in summer in this region, though not a very large proportion of the annual total Ragusa, which has a rainfall of about 60 inches, receives only one-eighth of it in the three summer months, June, July, August Trieste has rain all the year round, the Mediterranean type is there partly merged in the Alpine type, which is a combination of the three chief European types of Atlantic, Mediterranean, and Continental

The following particulars of some well-known places illustrate the relation of winter and summer temperatures in the Mediterranean region

	Lat	Mean Annual Rainfall	Jan Temp	July Temp	Range
Genoa	44° N	52 ins	45°	75°	30°
Marseilles	43° ,,	22 ,,	43°	72°	29°
Naples	41° ,,	34 ,,	46°	76°	30°
Athens	38° ,,	15 ,,	48°	80°	32°

North America—This continent has its greatest extension from south to north, and stretches from within the tropics to well within the Arctic Circle It therefore exhibits all the variations of climate due to difference of latitude which may be experienced in the normal planetary circulation of winds The great mass of western highlands introduces modifications due to altitude, for in that region there are differences of elevation ranging from below sea-level to nearly twenty thousand feet, which is, of course, well above the limit of perpetual snow

North America shows characteristically the differences between the western and eastern sides of a continent as well as those differences due to latitude and altitude On the western side, for example, British Columbia has the British type of climate, with prevalent westerly winds, considerable rain distributed throughout

the year, and a mild climate with a low range of temperature In corresponding latitudes on the eastern

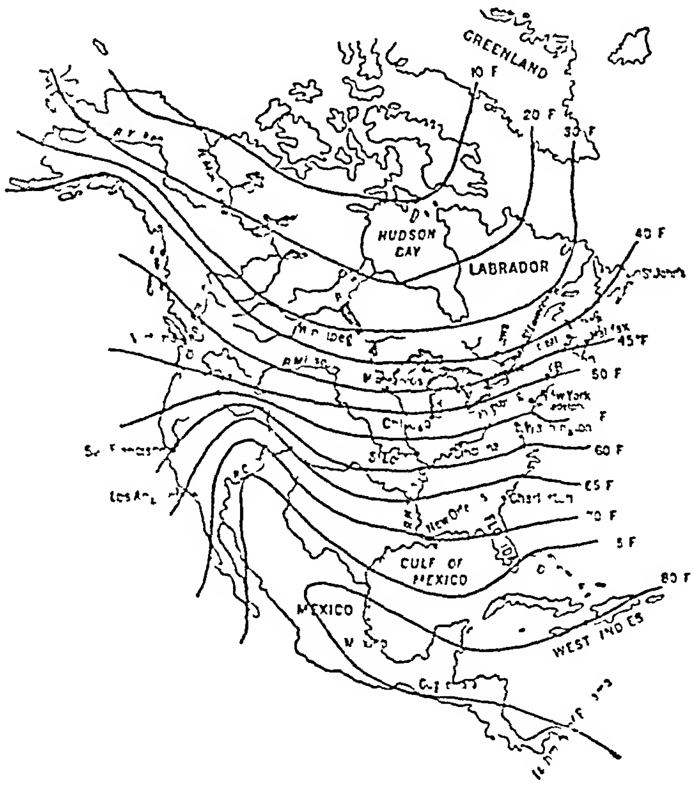


FIG 53 —NORTH AMERICA

Average annual isotherms reduced to sea level Note the way in which they slope from west to east on the whole

side there is the Laurentian type of climate, with a much greater range of temperature, colder winters, and a lower mean annual temperature The average annual isotherms thus slope from north-west to south east

across the northern part of North America, and there is a climatic difference of about 10° of latitude, that is, places on the eastern side have roughly the same average temperature as places in ten degrees higher latitude on the western side

Again, on the western side, in California, the Mediterranean type of climate obtains, with dry, warm summers and mild, rainy winters Immediately south of this zone comes the desert type of southern (Lower) California, Utah, and Arizona, corresponding to the Sahara in western Africa In corresponding latitudes on the eastern side there is a Chinese type well developed, with wet summers and cold winters In North America, however, the eastern climate is somewhat different from eastern Asia, for there is more rain throughout the year than in Asia The range of temperature is not nearly so great as in south-eastern China, where, as already mentioned, lowland snows are found nearer the equator than on any other part of the earth's surface Compare the climatic details of two places in China and eastern North America, in nearly the same latitude and otherwise similarly situated

	Lat	Rainfall	Jan Temp	July Temp
Wei hai-wei .	37°	22 ins	30°	76°
Cape Hatteras .	35°	63 ,,	46°	81°

also two in similar situations but in slightly lower latitudes

	Lat	Rainfall	Jan Temp	July Temp
Shanghai .	31°	44 ins	38°	80°
Savannah	32°	52 ,,	50°	81°

Central America and the West Indies lie within the trade-wind belt These winds blow from a warm ocean to a land where the highlands lie athwart their directions It must be emphasised again that the trade winds blow from colder to warmer latitudes, and are

thus essentially drying winds, but when they blow to lands where they are compelled to rise rapidly, the cooling due to rarefaction causes rapid precipitation and there is rain on the windward side of these lands The difference between windward and leeward sides is especially well shown in some of the West Indies The island Porto Rico, for example, has a heavy rainfall on its eastern and north-eastern side, while on the southern and south-western sides, beyond the mountains, irrigation is often necessary to secure the growth of the crops The same holds in mountainous Central America the eastern slopes have heavy rains, and are densely forested, the western slopes are much drier and healthier It is notorious how the towns and chief habitable areas are found on the western side of these mountains, the eastern lands, especially the lowlands, are swampy and malarial

A map of the annual rainfall of North America shows distinct belts running on the whole north and south A narrow belt of high rainfall on the west coast, the rainfall rapidly diminishing inwards, with a well-defined rain-shadow over the second line of mountains, a wide belt on the eastern side, with the rainfall diminishing progressively towards the west, with again a well-defined rain-shadow over the Rocky Mountains The western and eastern rain-shadows meet in the plateau regions and as may be expected, there is a considerable desert in the southern part of this region, extending through parts of Nevada, Utah, Colorado, New Mexico, and Arizona

To sum up the rainfall, there are two belts with over 60 inches per annum, a north-western coast belt, and a region lying in the east and south east There are three regions with less than 10 inches a comparatively small area in Mid-Mexico, a larger area in the south-west

plateau region of the United States as already mentioned, and the Tundra region of the north of the continent

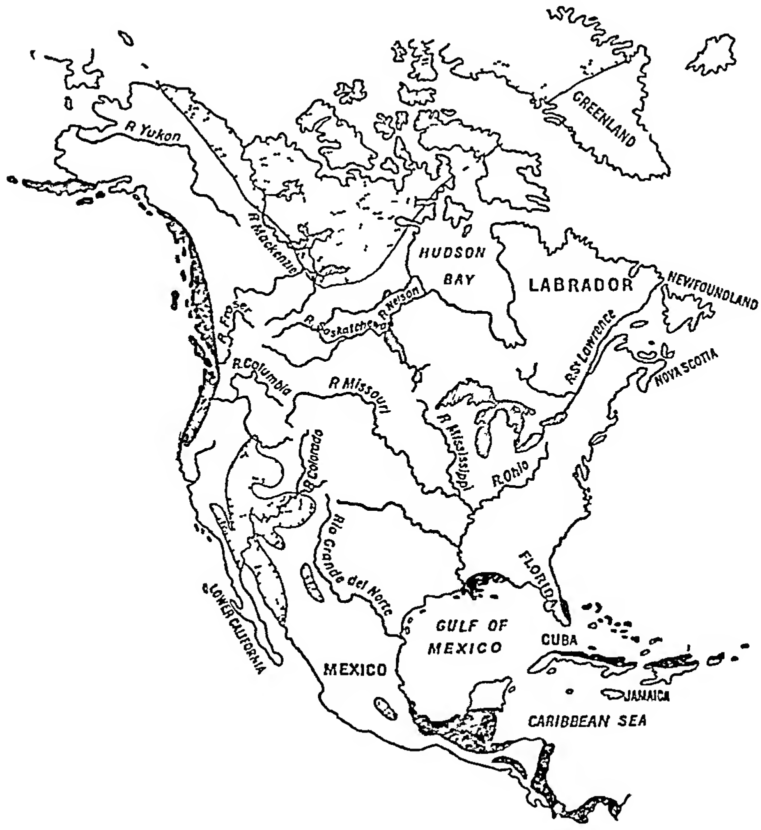


FIG 44 —RAINFALL, NORTH AMERICA

Regions of heavy and of light rainfall Black, over 60 inches per annum, stippled, below 10 inches per annum (*see* Text) Note that the heavy rainfall occurs on the western side in high latitudes, and on the eastern side in low latitudes

The continent also shows in a remarkably clear way the influence of position and structure on range of temperature The usual law holds that the seasonal

range increases with rise of latitude until the cold-temperate zone is reached, and the range also increases, on the whole, progressively inland Thus we may expect the greatest difference between summer and winter in the middle of the continent and in about latitude 50° to 55° The seasonal range is intensified to some extent by the direction of the mountains and the consequent distribution of the rainfall, and we therefore find in the great plains of Canada approaching the Rocky Mountains a difference of some 60° between the average temperatures of the coldest and the warmest months The climatic constants of Prince Albert on the North Saskatchewan river may be taken as a type

	Lat	Rainfall	Jan Temp	July Temp	Range
Prince Albert	53° N	13–15 ins	−3°	62°	65°

As further illustrating the range of temperature in different parts of North America, we may take three places in nearly the same latitude, on the west coast, in the middle, and on the eastern side We observe that the seasonal range of temperature is greater on the east than on the west, while, of course, that of the middle is greater than either

	Lat	Jan Temp	July Temp	Range
West Coast, Fort Simpson	54°	33°	58°	25°
East Coast, Rigolet, on Hamilton Inlet	54°	7°	50°	43°
Middle, Edmonton	53°	5°	63°	58°

The summer climate of Fort Simpson is very similar to that of the west of the British Isles, but the coldest month is some five to seven degrees colder than in Britain

North America also furnishes abundant illustrations of the variation of climate with altitude Referring almost exclusively to temperature, Mexico may be quoted as a good example In that country it has long been customary to speak of three successive zones, first

the *tierra caliente* (the hot land), the tropical lowland zone, where the climate is essentially hot and wet, especially on the eastern side. This continues up to some 3000 feet. Above it is the *tierra templada* (the temperate land), where the conditions are those of Northern California. This remarkably healthy zone extends from about 3000 feet to 7000 feet. Above this is the *tierra fria* (the cool zone), where the conditions are those of British Columbia. As Mexico extends for over 1000 miles from north to south, it is obvious that the figures given above must be understood in a general sort of way; fifteen degrees of latitude is clearly sufficient to make a great difference in the height at which these successive temperature zones succeed each other.

Some Local and Secondary Features in North America

The climate of North America has been studied from the point of view of general planetary distribution as modified in the first degree by the shape of the continent, the direction and arrangements of its highlands, and its relation to the neighbouring oceans. There are in all continents local developments of a secondary order, the full study of which could not be undertaken in a general book like the present.

Three of the best known from North America may, however, be fittingly selected as illustrating general principles. These are *whirlwinds*, *tornadoes*, and *Chinook winds*, quite local and secondary disturbances in the general circulation of winds, but of considerable interest and notoriety because of their great importance to man.

Whirlwinds are developed in the hot, dry plateaux of the great western mountain system, and in the great plateau-plains west of the Mississippi. As the name indicates, there is a *whirl* of air, which is, however, of

quite local character It may have a diameter of some 50 to 100 feet, and the spiral, whirling column may rise to 3000 feet Such whirlwinds occur on the hot plains and plateaux in the latter part of very hot summer days The air over the hot, parched plains becomes intensely heated, quite locally, inflowing currents are set up, and as they probably approach the region of heated air with different velocities a spiral motion is set up, and the ascending air laden with dust particles, presents the appearance of a swaying, whirling column which moves across the parched plain with a very considerable velocity

Tornadoes are much the same on a grander scale, and are probably the same in origin These are most numerous in the Mississippi valley, where they often sweep across the country at the rate of 30 miles an hour [1] They are often so violent that a clean-cut path marks their track, in which trees and buildings are alike swept away They usually occur in the afternoon or evening of warm, sultry days, when the air has been intensely heated over some lowland area The local indraught of air upsets the equilibrium over the hot plains, and a whirlwind on a great scale is set up These are the most destructive storms of the continent, and are justly the most dreaded

Chinook Winds.—These are warm, drying winds which sweep from the snow-clad Rocky Mountains down into the high plains and valleys to the east These winds blow in winter and in spring, and often cause rapid melting of the winter snow over a comparatively wide area They thus make some parts of these high plains available for stock-raising much earlier than would otherwise be the case Their origin is the same as

[1] This is the rate of movement of the whole tornado, the winds may blow with a velocity up to 200 miles an hour

that of the famous *fohn* winds of the Alps An area of low pressure is set up on the eastern side of the Rocky Mountains owing to some local disturbance, and air is drawn from over the mountains The air which passes over the mountain is first of all cooled by rarefaction due to lowering of pressure Most of the moisture which is contained thus falls on the windward side of the mountains, chiefly, of course, as snow The dry, rarefied air passes over the mountain crests and descends towards the plains Compression, of course, occurs, and consequent rise of temperature, and the winds reach the plains or valleys as warm, drying winds, which lick up the snow almost as by magic The Chinook winds are developed best in the valleys on the eastward side of the Rocky Mountains because of the general direction of the winds in that region In the Alps the *fohn* winds occur in the valleys to the north of the main chains

India.—India is the popular example of a region with monsoon climatic conditions These conditions hold in Asia from Manchuria to Baluchistan, and India and Further India show the characteristic features As in all other regions, world position and structure play their part in determining the peculiar features of the climate The great continent to the north, the ocean to the south, the shape and position of the peninsular part of India, the position with respect to the equator (the Tropic of Cancer crosses continental India, and thus peninsular India is entirely within the tropics), these are the chief determining factors

It is not necessary to repeat the account of monsoon conditions and causes, it is more to the point to state how they affect India in particular The "winter" monsoon winds blow from north, north-east or north-west, and are generally light in character The earlier part,

from mid-December to the end of February, is the cool season in much of India, then the monsoon weakens and the very hot weather comes and lasts until the end of May or mid-June May is the hottest month in most parts of the north of India, and average temperatures for that month are usually over 90° F

The south-west or wet monsoon blows from about the middle of June to the end of September or middle of October It is established on the break-up of the hot, dry weather, after a series of attempts, during which there is unsettled weather with many intense storms During the season May–September rain falls on most days, and the weather is hot and steamy In the peninsula the monsoon meets the Western Ghats—the scarp edge of the plateau—almost at right angles, and there is consequently a heavy rainfall The middle of the Deccan is in a partial rain-shadow where the fall is slight compared with the western edge A branch of the monsoon blows over the hot Bay of Bengal, and becomes thoroughly saturated with water vapour This air current meets the foot hills of Upper Assam, and as it ascends these the air is rarefied and cooled, and the condensation of its abundant moisture produces the heaviest rainfall known The rainfall of Cherrapungee in the Khasia Hills reaches the enormous total of more than 400 inches per annum, and only about 1 per cent of this falls in the four months November to February

The mighty Himalaya system deflects the rain-bearing monsoon, and air is also drawn in by the low-pressure area to the west up the Ganges valley, and thus carries a moderate rainfall even so far as the North-West Provinces and the Punjab The north east monsoon is, of course, a dry wind for most of India, but Ceylon and the southern Coromandel coast receive some rainfall from the wind which has gathered moisture from its journey

over the Bay of Bengal, and from the retreating south-west monsoon Trincomali on the *east* coast of Ceylon has a rainfall of over 60 inches per annum

The peculiar case of Ceylon may be further illustrated There is considerable rain in every month except February The rainfall is more of the equatorial type with two maxima, in March–May and October–December respectively April and May are hot and wet (though not so hot as in the Ganges Valley), and to escape this hot, wet season there have been established on the hills sanatoria which are now famous, and of great importance to European residents both in Ceylon and Southern India Newara Elsya is at an elevation of over 6000 feet, and has an average temperature of 58°, with a very low range Of course, Ceylon being almost on the equator, and being an island, cannot have a great seasonal range The following statistics are significant

	Lat	Rainfall	Jan Temp	July Temp
Colombo	7° N	88 ins	79°	80°
Trincomali	8½° ,,	63 ,,	78°	83°

To return to the general study of India, the seasonal range increases (*a*) with distance from the equator, (*b*) with distance from the sea, hence there is the considerable range, for low latitudes, in the Upper Ganges Plain of about 26°, in the Punjab of over 30° The seasonal range is also great on the plateau, and reaches about 25° The statistics of Agra in the Ganges valley and Multan in the Punjab are sufficiently important to be given

	Lat	Rainfall	Jan Temp	July Temp
Agra . .	27°	28 ins	60°	86°
Multan .	30°	7 ,,	57°	93°

The Thar (*i e* Desert) in North-Western India is almost rainless The winds in that region come for the

most part from the lands west and north west There is a low-pressure area in the Punjab and air is drawn in to this according to the usual rule north of the equator, that is counter clockwise The desert is south of this low-pressure area, hence winds come from the west and north-west The lower Indus valley is also nearly rainless, and its cultivated areas depend upon the overflow of the Indus or upon irrigation The river is fed by the snows of the Himalaya and the winter snows of the Upper Punjab

Karachi, west of the delta, and the great place of export for the wheat and barley of the lower Indus plain, has an average rainfall of 8 inches Its seasonal range of temperature, 65°–83°, is comparatively low because of proximity to the sea

The southern side of the mighty Himalaya exhibits very well the consequences of the usual variation of temperature with altitude The tropical malarial *terai*, densest towards the east, occurs at the foot, and tropical vegetation continues upwards to about 4000 feet Deciduous vegetation (indicating a temperate climate) follows, gradually passing into coniferous forest, and this continues to 11,000–12,000 feet Alpine pastures succeed with tundra vegetation highest of all, to about 17,000 feet and, of course, above that is the zone of ice and snow The magnificent intermont valleys, especially such as the great vale of Kashmir, show the [illegible] climatic conditions and the characteristic vegetation thus in the valleys of Sikkim at 7000–8000 feet brilliant rhododendrons are a prominent feature

Australasia —The essential features of the climate may again be best grasped by noting (1) that Australia is entirely south of the equator, between latitudes 11° S and 39° S, and that the Tropic of Capricorn crosses it almost in the middle, (2) that the continent is of

compact structure, and has its greatest extension from west to east parallel to the equator, and (3) that it has the open ocean on all sides except the north

Without elaborating the different regions very fully, the establishment of four climatic divisions will be readily understood (1) The tropical monsoon region of the north, (2) the region of south-east trade winds in the east and south-east, (3) the south-west and south, with Mediterranean conditions, and (4) a very dry region in the western middle part.

The monsoon region is in the north and north-east The rainfall mostly comes with the summer monsoon, but it is not so heavy as in some regions owing to the absence of very high mountains to effect a very large condensation The fairly heavy rainfall does not extend very far into the interior The seasonal range of temperature is low, increasing, of course, in the interior The statistics of Cape York on York Peninsula and Port Darwin to the west of Arnhem Land may be used to illustrate this region Both have very wet summers from about the end of December to the end of March, and are very dry from June to September

	Lat	Rainfall	Jan Temp	July Temp
Cape York	11° S	83 ins	81°	77°
Port Darwin	12° ,,	64 ,,	82°	78°

South Queensland and New South Wales are in the region of south-east trade winds The mountains are wider, but not very high There is, however, a well-defined rain-shadow, especially towards the south where the mountains are somewhat higher The western slopes of the hills are therefore drier and the plains of the Darling-Murray system receive a rainfall diminishing in amount towards the west, until the desert with less than 10 inches is reached The temperature

ranges in the interior are, of course, considerable Sydney and Bourke (on the Darling River) may be taken as typical studies of the trade-winds region

	Lat	Rainfall	Jan Temp	July Temp	Range
Sydney	33°	47 ins	71°	53°	18°
Bourke	30°	15 ,,	84°	50°	34°

The south and south-west receive winter rains from the westerly winds, which blow when the trade winds have swung to the north This region corresponds to the Mediterranean and to middle California The summers are hot and dry The most favoured parts are the southward extension of the continent in West Australia and South Australia and Victoria The Great Australian Bight carries its coast lands too far north, where little rain falls Perth and Adelaide, the two capital towns, may be taken as examples Both have most of their rains in the winter months, May to August The winters are cool and the summers decidedly hot

	Lat	Rainfall	Jan Temp	July Temp	Range
Perth	33° S	33 ins	76°	55°	21°
Adelaide	30° ,,	20 ,,	74°	51°	23°

The dry region occupies most of the western tableland and some parts of the central lowlands The zones of annual rainfall curve round it somewhat eccentrically, with its own centre about on the tropic and in the longitude of the western third part of the continent (The student will, of course, study a rainfall map, together with an orographical map) The rainfall is low, the range of temperature, both seasonal and daily, is considerable The arid region corresponds to the Sahara, though fewer oases seem to exist than in the great African prototype Alice Springs on the overland telegraph route, and almost in the latitude of the tropic,

and Strangeway Springs south of Lake Eyre, may be taken as typical places

	Lat.	Rainfall	Jan Temp	July Temp	Range
Alice Springs (Altitude about 2000 feet)	23° S	10 ins	87°	52°	35°
Strangeway Springs	27° ,,	6 ,,	84°	55°	29°

The three large islands and island groups of Australasia may be very briefly considered New Guinea is almost equatorial, and has very heavy tropical rains The mountain barrier which runs east and west rises to 13,000 feet, and separates the island into two climatic provinces The north has very heavy monsoon rains from December to March, that is, in the southern summer. The south receives mostly winter rains from the south-east trades, which bring rain from the southern Pacific when the sun is north of the equator. The temperature is high and the seasonal range is low Data are still wanting for most parts, but the seasonal range at Port Moresby seems to be little more than 3° or 4°, that is, from 81°–82° in January to 77°–78° in July

New Zealand—North Island is obviously Mediterranean in latitude, and it has a climate of that type somewhat modified Winter rains are heaviest, but the surrounding ocean modifies the usual summer drought of Mediterranean regions South Island and the southern part of North Island are in the region of prevalent westerly winds These winds are more perfectly developed in the Southern Hemisphere than in the Northern, owing to less interference by great land masses The westerly side is therefore the rainy side, as in Britain and France The western slopes of the New Zealand Alps have a very heavy rainfall, there being over 100 inches on most of the west coast. The rainfall

map shows the rain-shadow of the mountains in a way that reminds one of the rain-shadow of Scandinavia. The plains to the east have only an average of about 20 to 25 inches, and are therefore well adapted for sheep-rearing, which has become the greatest industry of South Island. North Island has no dominant mountain range like that of South Island, and the rainfall is therefore more evenly distributed over the whole island. Owing to the insular position the whole of New Zealand has a comparatively low seasonal range.

	Lat	Rainfall	Jan Temp	July Temp	Range
Auckland	36° S	44 ins	67°	53°	14°
Wellington	41° ,,	51 ,,	62°	46°	16°
Christchurch	43° ,,	25 ,,	62°	43°	19°
Hokitika	42° ,,	118 ,,	60°	46°	14°

Tasmania is also in the region of prevalent westerlies and has rain at all seasons. It is climatically the counterpart of north-western France. The west is wetter than the east owing to the position of the mountains and the drier eastern slopes are suitable for sheep-rearing. The rainfall on the west reaches 80 inches or more; on the east coast it descends to 20–25 inches. Hobart may be taken as an illustration, though its rainfall is low owing to its being in the rain shadow.

	Lat	Rainfall	Jan Temp	July Temp	Range
Hobart	43° S	24 ins	62°	46°	16°

South Africa.—We shall include here all Africa roughly south of the Zambesi, which will make it correspond broadly to Australia. The differences are important, however. Australia is an island; South Africa passes gradually into equatorial Africa. Australia has its greatest extension east to west; South Africa has its greatest extension north to south. The region as defined above merges into the tropical types

—tropical lowland towards the east, tropical savana in the middle, tropical desert in the west

Owing to comparative uniformity of structure the different provinces are determined by relation to the planetary system and influence of neighbouring oceans more than by differences in build The three well-defined provinces are (1) The south-east trade-wind region, including Natal, the Orange Free State, the Transvaal, and Portuguese East Africa (2) The extreme south and south-west, with a Mediterranean climate, and (3) the desert region of the middle and west

The south-east trade winds meet the eastern mountain scarp of the Madagascar table-land, and the lower western parts of this large island have a pronounced rain-shadow Antananarivo has a rainfall of over 50 inches per annum, Tamatave one of 90–100 inches Most of the rain falls in summer, as may be expected Natal rises in terraces until the great scarp of the Drakensberg is reached The rainfall is thus caught on the south-eastern side, and the high veld of the interior is relatively bare and dry The eastern margin of the high veld is thus much more fertile than the western part, which merges into the deserts of the west

	Lat	Rainfall	Jan Temp	July Temp	Range
Durban . .	38° S	80 ins	76°	64°	12°
Pretoria (4750 feet)	25° ,,	27 ,,	71°	52°	19°

The extreme south and south-west fall within the zone of summer trades and winter westerlies, hence there is a small region with rain at all seasons, from the south-east trades in the summer, and from the westerly winds in winter This is a modified Mediterranean type, with some rain in the summer instead of dry trades as in the type region As no part of South Africa reaches 35° S latitude, it is only the extreme

south which receives the Mediterranean type of rains It corresponds with Morocco rather than with the Iberian peninsula

The places selected for illustration are

	Lat	Annual Rainfall	Jan Temp	July Temp	Range
Cape Agulhas	33° S	16 ins	67°	54°	13°
East London	33° ,,	24 ,,	70°	57°	13°

The desert region includes northern Cape Colony, Bechuanaland, and Damaraland, the latter two being on the borders of the Kalahari desert Rain seldom falls except on the higher parts The seasonal ranges of temperature are considerable, and the daily range is often very great On the dry plateaux the cold of the nights is frequently intense This is mainly a stock-rearing region as there is not enough rain for agriculture, and there are few rivers from which water for irrigation can be derived Angra Pequena on the coast and Windhoek (altitude 5400 feet) on the plateau are selected as the types

	Lat	Rainfall	Jan Temp	July Temp	Range
Angra Pequena [1]	26° S	(Scarcely any)	67°	57°	10°
Windhoek (5400 feet)	22° ,,	15 ins	74°	56°	18°

[1] A cold current which sets along the coast from the south reduces the temperature of Angra Pequena very considerably

GRAPHICAL REPRESENTATION OF *RAINFALL* AND *TEMPERATURE*

To help the reader to visualise the two features of climate (rainfall and temperature) of a number of typical towns in various parts of the world, a series of graphs, followed by a few suggestive studies, is given on the following eight pages, 320–327

EUROPE

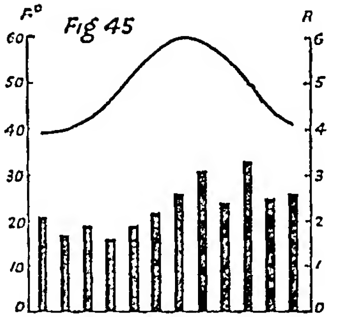


Fig 45

R 21 17 19 16 19 22 26 31 24 33 25 26 = 27 9
F° 39 40 42 46 52 57 60 59 56 50 44 41 R = 21°

LIVERPOOL 53°25 N

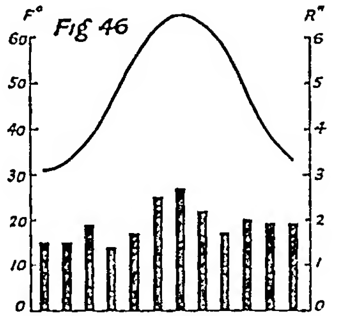


Fig 46

R 15 15 19 14 17 25 27 22 17 20 19 19 = 22 9
F° 31 32 37 46 55 62 65 63 57 48 38 33 R-34°

BERLIN 52°32 N

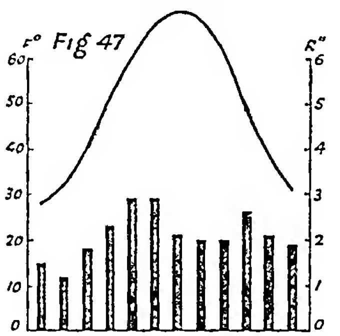


Fig 47

R 15 12 18 23 29 29 21 20 20 26 21 19 = 25 3'
F° 28 32 40 51 60 67 70 68 61 51 39 31 R 42°

BUDAPEST 47°30 N

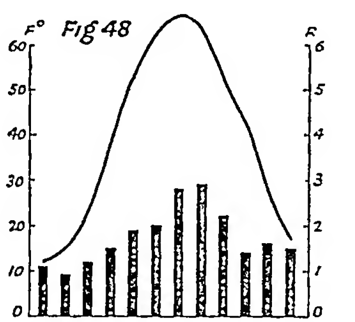


Fig 48

R" 11 09 12 15 19 20 28 29 22 14 16 15 = 21 0
F° 12 15 23 38 53 62 66 63 52 40 26 17 R-54°

MOSCOW 55°45'N

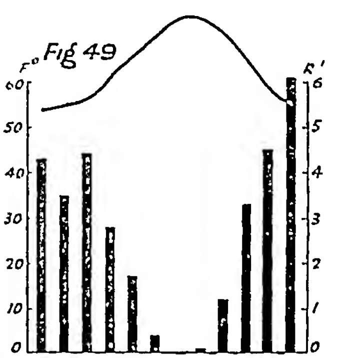


Fig 49

R' 43 35 44 28 17 04 0 01 12 33 45 61 = 32 3"
F° 54 55 56 61 65 70 74 74 71 65 59 55 R 20°

GIBRALTAR 36°10'N

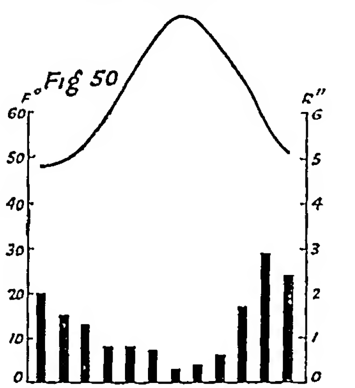
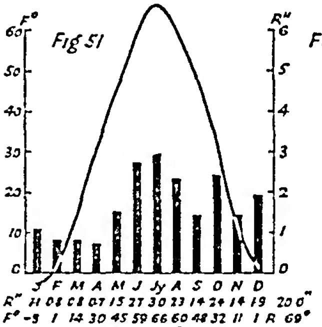


Fig 50

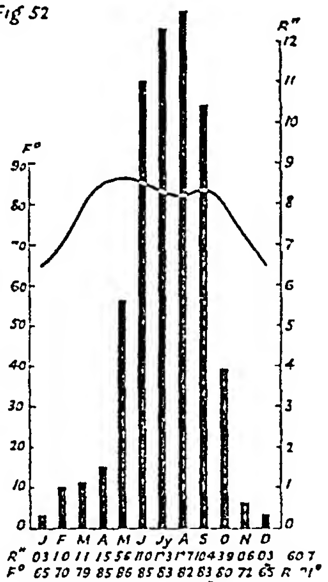
R 20 15 13 08 08 07 03 04 0.6 17 29 24 = 15 4'
F° 48 49 53 60 68 76 81 80 74 67 57 51 R-33°

ATHENS 37°59'N

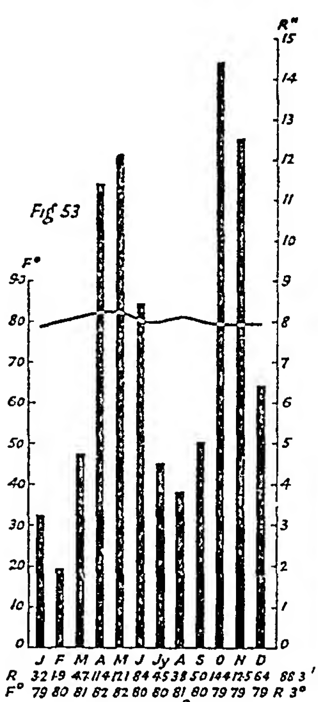
ASIA



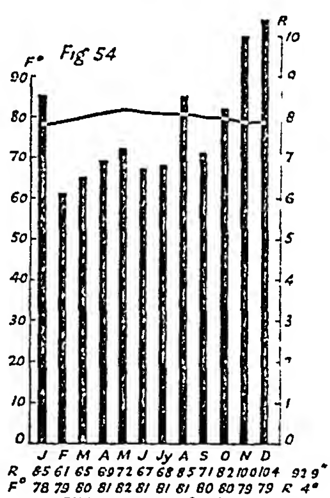
TOMSK 56°30 N



CALCUTTA 22°34 N

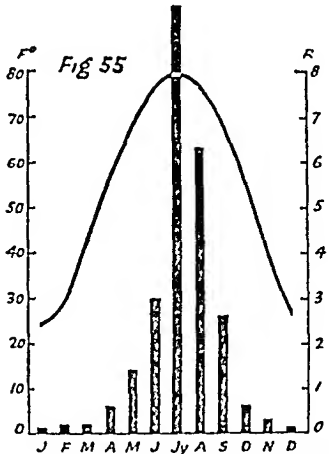


COLOMBO 6°56 N



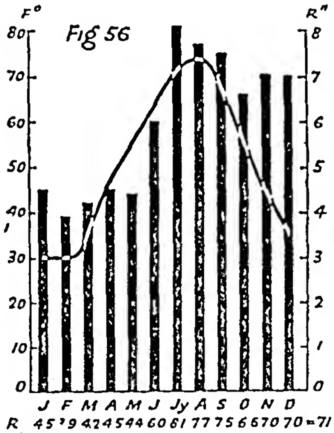
SINGAPORE 1°17' N

ASIA AND NORTH AMERICA



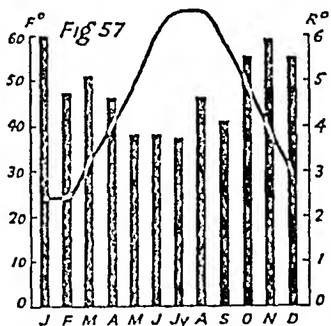
R′ 01 02 02 06 14 30 94 63 26 06 03 01 = 24 8′
F° 24 29 41 57 68 76 79 77 68 55 39 27 R 55°

PEKING 39°54′N



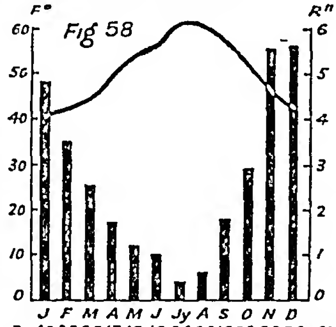
R 45 39 42 45 44 60 61 77 75 66 70 70 = 71 4′
F° 30 30 36 47 56 64 71 74 67 55 44 35 R 44°

AKITA 39°43′N



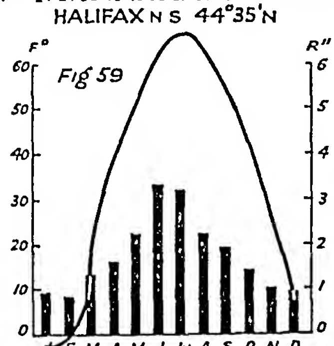
R″ 60 47 51 46 38 38 37 46 41 55 59 55 573″
F° 24 24 32 40 49 58 65 65 59 49 40 29 R 41°

HALIFAX N S 44°35′N



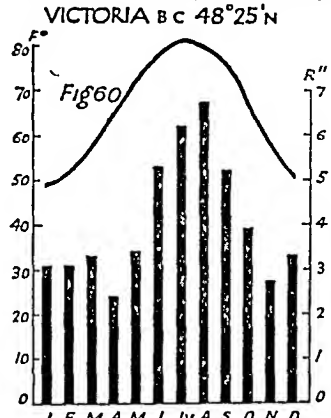
R 48 35 25 1·7 12 1·0 04 06 18 29 55 56 = 31 5″
F° 40 42 44 49 54 56 61 60 57 52 46 43 R = 21°

VICTORIA B C 48°25′N



R″ 09 08 1·3 16 22 33 32 22 19 14 10 09 20 7″
F° -3 -1 15 39 51 62 66 63 54 42 25 7 R = 69°

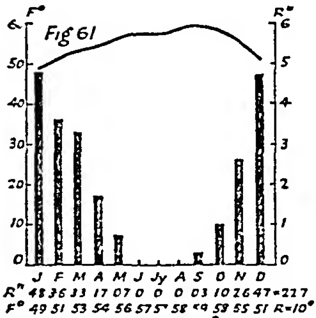
WINNIPEG ALT 1,500′ 49°55′N



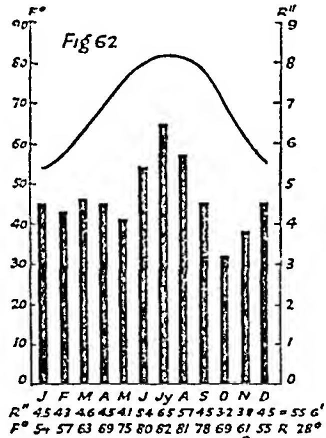
R′ 31 31 33 24 34 53 62 67 52 39 27 33 = 48 6″
F° 49 52 57 64 72 78 81 80 76 67 58 51 R 32°

CHARLESTON S CAROLINA 32°50′N

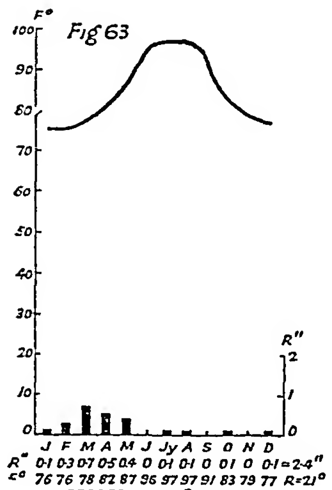
NORTH AMERICA AND AFRICA



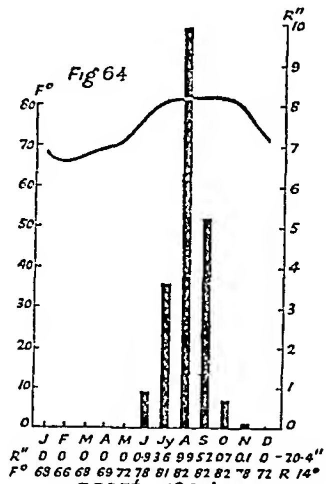
SAN FRANCISCO 37°48 N



NEW ORLEANS 30°N

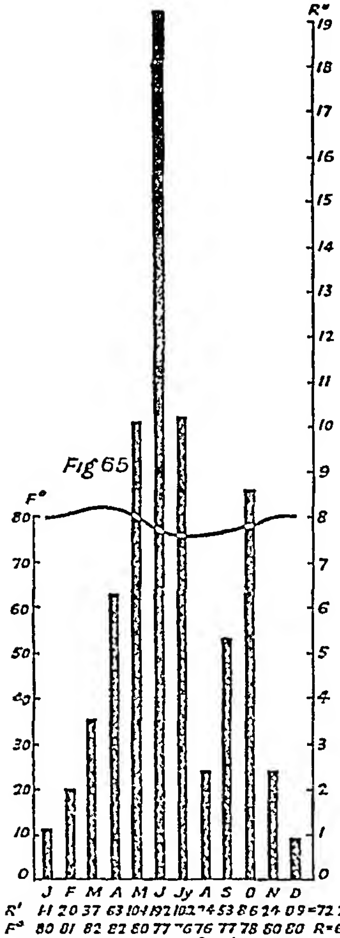


BERBERA 10°27 N

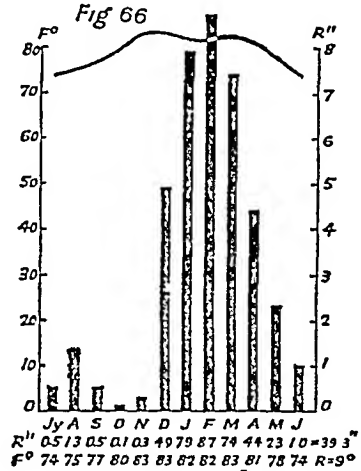


GOREÉ 14°39'N

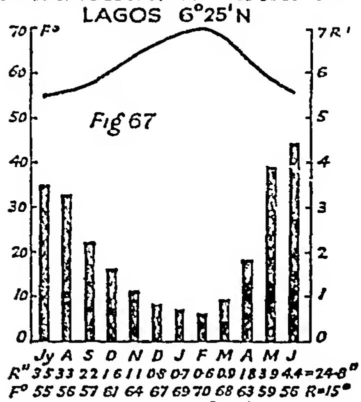
AFRICA



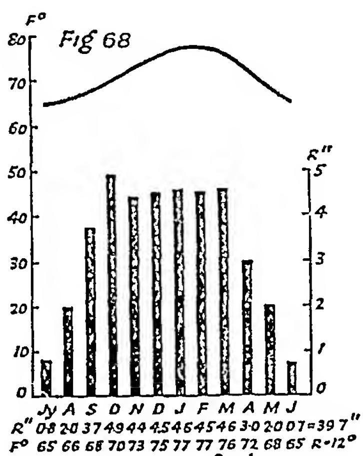
LAGOS 6°25'N



MOZAMBIQUE 15°S

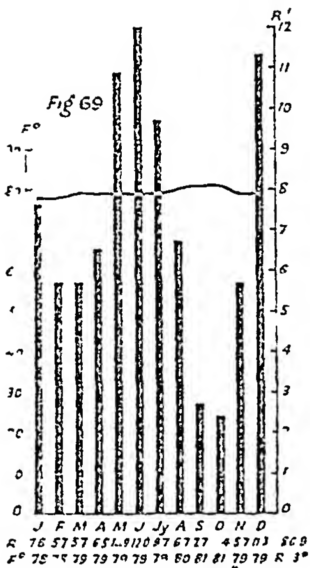


CAPE TOWN 33°56'S

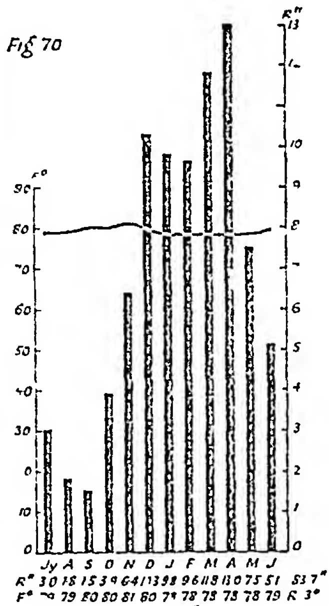


DURBAN 29°52'S

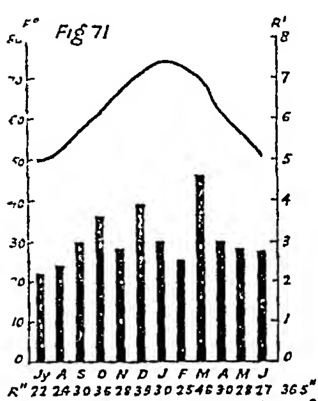
SOUTH AMERICA



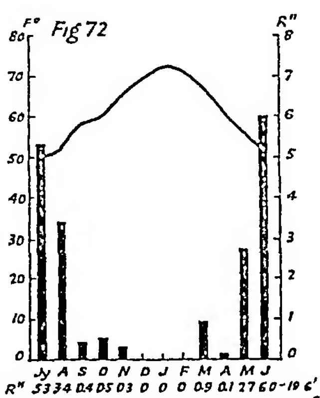
GEORGETOWN Br. Gui 6°50 N



MANAOS 3°10 S

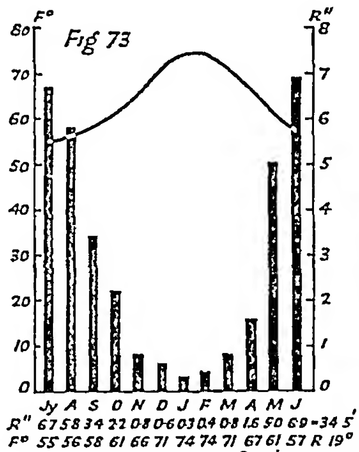


BUENOS AIRES 34°35'S

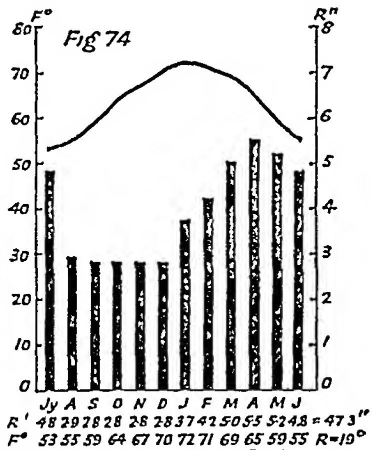


VALPARAISO 33°2'S

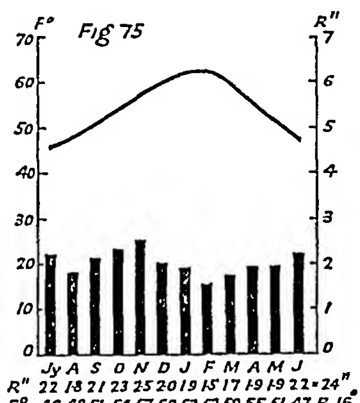
AUSTRALIA AND NEW ZEALAND



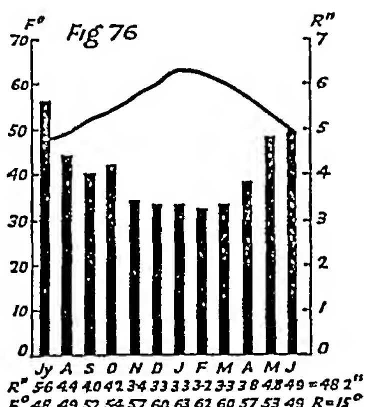
PERTH W AUSTRALIA 31°57'S



SYDNEY N.S W 33°52'S



HOBART TASMANIA 42°53'S



WELLINGTON N Z 41°16'S

CLIMATIC STUDIES BASED ON THE PRECEDING DIAGRAMS

(Note that in the case of places in the Southern Hemisphere the year is made to begin with July so that the diagrams shall be the more readily compared)

(*a*) Compare the diagram for Liverpool with those for Victoria B C , and Hobart, Tasmania, noting similarities and differences

(*b*) How do the climates of Halifax N S Winnipeg and Victoria B C differ from each other ? Compare with the climates of Liverpool Berlin, and Moscow

(*c*) Compare the ranges of temperature of Halifax N S Akita, and Peking with those of Hobart, San Francisco and Liverpool and note that the terms *continental* and *insular* are not suitable for denoting great extremes and small extremes respectively

(*d*) In what respects are the climates of Gibraltar San Francisco, Valparaiso, Cape Town and Perth (Australia) similar, and why ? Note the July temperature of San Francisco is somewhat abnormal and attempt an explanation

(*e*) Compare the climates of Buenos Aires, Durban, and Sydney, N S W How does the climate of Peking differ from them ? Compare Peking with Akita, and explain the differences noted

(*f*) In what respects are the climates of Singapore Colombo Lagos, Georgetown and Manaos similar, and how do they differ ?

(*g*) Note that Berbera, which is over 10° from the equator has a far hotter July than any of the five places which are less than 7° from the equator, and attempt an explanation

The above are given as examples of interesting studies , the reader will have little difficulty in suggesting many others It is through such studies that the meaning and use of climatic diagrams and also the principles of Climatic Geography may be more completely understood

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SECTION C

GEOGRAPHY OF PLANTS AND ANIMALS BIOLOGICAL GEOGRAPHY

CHAPTER XVI

GENERAL PLANT GEOGRAPHY

The growth of plants is controlled by physical circumstances, chief among which are heat, light, water in the air and soil, and the nature of the soil and subsoil Thus the climatic factors which mainly determine the character and luxuriance of vegetation are the temperature, the amount of sunlight, and the rainfall It may be said that in tropical regions climate overrules soil and subsoil, but in temperate climates the nature of the soil is of great importance It is easy to see, from well-known concrete examples, that the nature of the soil is a very important factor in cooler regions, thus central Ireland has a climate that is not very different from that of the Lancashire and Cheshire plain, yet its vegetation is different The Betuwe and Veluwe of Holland, the "Good Island" and the "Bad Island," are in the same climatic province, the fertility of the one is remarkable, the relative barrenness of the other is striking The Landes of the south-west of France are in the same latitude and have a climate not very different from that of the valley of the Rhine, the sandy subsoil of the

one, and the fertile mixed alluvium of the other make a great difference in the productivity On the whole, climate, in the wide sense, must be considered the primary factor in the control of vegetation, and we shall therefore study plant associations as determined by climate

The study of plant associations is the special science of Plant Ecology, which is obviously a compound of Botany and Geography It is beyond the limits of this book to attempt anything like an extensive study of that branch of science, we shall confine ourselves to plants and plant associations which are important to man, and thus bring this part of the subject into line with the general scope of the work Broadly speaking, trees may be taken as representative of plant life in general, and this point of view will be emphasised in this and the next chapter The boundaries and limitations of forests are found to agree broadly with the boundaries of climatic provinces, and we shall therefore subdivide the study of plant life according to those different climatic provinces

HOT LANDS

Broadly speaking, these are the lands between the tropics of Cancer and Capricorn, a belt of the earth's surface 47° in width Their limits are approximately the two desert belts which lie on either side of the Equator The equatorial lowlands may be taken as the starting-point, and from there we may pass on the one hand to those tropical latitudes where the rainfall is seasonal or not so heavy, and on the other to those plateaux and mountains where the same changes occur owing to change of altitude There are four fairly distinct types in these hot lands

(1) The Equatorial Lowlands, or Amazon-Congo Type

PLATE XVIII.—EQUATORIAL FOREST, CONGO BASIN, SHOWING RICH UNDERGROWTH AND PARASITIC CREEPERS

PLATE XIX — SANDWICH ISLANDS AN HAWAIIAN SUGAR PLANTATION

(2) The Summer Rains or Monsoon type, southern India Type

(3) The Tropical Highlands, or Uganda Type

(4) The Tropical Desert, or Sahara-Kalahari Type

Equatorial Lowlands — Amazon-Congo Type — The climatic characteristics are rain throughout the year and a uniform high temperature There may be two relatively wet and two relatively dry seasons, near the equator itself, the two wetter seasons occurring soon after the equinoxes, and as we get farther away from the equator there are wet and dry seasons, the latter increasing in length the farther we go from the equator

The atmosphere is hot and steamy, and plant growth is rapid and exuberant These lowlands are covered with dense primeval forests, in which an immense number of trees struggle for existence Prof I C Russell is responsible for the statement that there are probably more species of trees in 100 sq yards in an equatorial lowland forest than in 100 sq miles in a forest of central Canada

The forest is so dense that only a diffused greenish light, a sort of twilight, reigns in the lower glades, while the successful competitors above are bathed in the intense tropical sunlight from a sun that is never far from overhead at midday in any season The undergrowth is very dense, and mosses, lichens, and fungi grow on the damp mould below, while creepers and parasitic plants climb up to the light above, and hang their aerial roots or *lianas* in the spaces below Numerous species of vines, palms, and tree ferns mingle with an immense number of species of woody trees, whose great roots spread over the rich moist soil, while many of the trees develop root-like buttresses eight or ten feet from the ground

The stuffy, gloomy vault, hot and moist, like the

atmosphere of a palm-house, is generally thinly peopled It has to be cleared before man can grow his food plants in security, and it is one continual fight between man and nature, for the forest rapidly reconquers any clearing, and constant vigilance and effort are the price he must pay to hold his own In the more favoured localities gardens of wonderful luxuriance have been won, and the natural products of the forest are cultivated

The temperature throughout the year is so uniform that there is no one time for leafing and flowering of the trees and other plants They have adapted themselves to some very slight change in the atmospheric conditions, and so there are always some plants bursting into leaf and putting forth flowers or producing seeds.

The vegetable products of the equatorial lowland forest are numerous and valuable Among the most important is the widely-spread coco-nut palm, whose fibres, leaves, and fruits are all useful to man, mahogany, ebony, greenheart, and lignum-vitæ among timber trees, and logwood and brazil-wood among dye-woods The plantain, the banana, and the yam, the sugar cane, the cacao tree, the sago palm, and the manioc are among other useful plants common in these forests Caoutchouc, rubber, balata, and gutta-percha, many spices and condiments such as vanilla, cloves, nutmeg, and ginger, are other important products from the equatorial forests In addition to all these, rice may be mentioned, though its home is rather in the monsoon lands

This forest type has its greatest development in the basin of the Amazon, the lower Guinea lands, and the basin of the Congo Iquitos, in the Amazon valley is 2° colder in July than in January, the average temperatures being 77° and 79°, with a rainfall of over 100 inches Para, at the mouth of the great river,

has a temperature in January of 78° and November, 80°, and a rainfall of about 88 inches Akassa, at the mouth of the Niger, has January 78° and July 76°, with a rainfall of 144 inches Libreville, in French Equatorial Africa, January 78°, July 73°, and rainfall about 100 inches, these may be taken as types of the climates of these equatorial lowlands

Summer Rain and Monsoon Type—South India Type—Passing from the equatorial lowlands with perennial rains we come to regions where there are distinct dry and wet seasons the rains come in the hot season The climatic characteristics of importance to plant growth are the occurrence of a well-marked period of drought, a less total rainfall, a greater seasonal range of temperature, and the occurrence of strong dry winds in the "winter" or dry season

Forests are densest, other things being equal, where the temperature is most uniform and the atmosphere is always moist Hence in lands with monsoon and summer rains the forests are different in type from those of the hot, wet equatorial lowlands, the trees over a wide area are more often of the same species, the forest is much more open, there is a periodicity of growth and many trees shed their leaves during the dry season

The chief regions where this type holds are India, Burma and Siam, Northern Australia, Central America, and the Guiana lowlands The teak forests of Java, the Malay Peninsula and Burma show the alternation of the dry season and the summer rains very well in the falling of the leaves Teak is well known as one of the most useful hard timbers

The forests in this zone are not so rich in useful products as the wet equatorial lowlands, but the ground is more easily cleared and the conditions are healthier Hence these regions have always been more thickly

peopled, and highly developed and prosperous agricultural races are found there Some of the products are the same as from the hot rainy forests, such as mahogany, logwood, the oil palm, rice, sugar, and the banana Coffee, tea, indigo, jute, maize, wheat, barley, and cotton can all be grown in these lands Maize may be regarded as the typical cereal crop, wheat and barley are grown as winter or dry season crops, often by the aid of irrigation, as in the lower valley of the Indus

The Tropical Highland Type — The Uganda or Ecuador Type —From general principles it will be readily understood that the two types already discussed will be modified at a considerable altitude, and a new type will result, especially on the higher tropical plateaux The equatorial lowland type holds up to roughly 3000 to 4000 feet, above that gradually a modified type is established The three or four ascending zones of climate already mentioned determine corresponding vegetations The climatic essentials are comparatively low seasonal range owing to low latitude, but a considerable general lowering of temperature owing to altitude The general climate is that of cool temperate or warm temperate lands according to elevation Quito has already been quoted as having "perpetual spring" it is 8000 feet above sea level There may be, and usually is, a considerable difference between night and day, and the night is sometimes very cold The temperatures of two places in Africa and America are given to illustrate the "perpetual spring" character of the climate

Fort Smith, on the Uganda Railways, on the Kikuyu Plateau, Uganda —Latitude, 1° S Height, 5200 feet January temperature, 63°, July temperature, 58°

Bogota, on the Columbian Plateau, S America —

Latitude, 4° N Height, 8700 feet January temperature, 58°, July temperature, 57°

Maize, wheat, and barley are the cereals of these plateaux, and Mediterranean fruits, such as pineapples, oranges, apricots, are grown The mulberry, for silk flourishes in many parts The grass lands, where the rainfall is sufficient, feed large herds of cattle, llamas and sheep

These typical plateaux may be too dry in places, if they lie between great mountain ranges, and are thus in a double rain shadow, in such circumstances irrigation is necessary for the rearing of the cereal crops and fruits mentioned [1]

Tropical Desert Type, or Sahara Type—In the study of climates and the establishment of climatic provinces it was pointed out that near the latitudes of the tropics on the western side of the continents deserts are found, and the circumstances determining them were discussed It will be remembered that these deserts are found in the track of the trade winds The study of a rainfall map of Africa or Australia shows how the regions of summer rains gradually pass into these western desert regions as we go farther from the equator The plant life varies accordingly, and there is usually a gradual passage from summer-rain forests through drier grass lands with scattered trees to semi desert, and finally thorough desert The climatic characteristics are, of course, absence or rarity of rain, and a great range of temperature both between day and night and between summer and winter It will be remembered that the high temperature belts are found in these desert regions (*see* again Temperature Maps of the continents) A great deal of the surface of these deserts is covered with sand dunes, with, of course, very little vegetation, but wherever subterranean water is available, or where

[1] See Miss Carrier's *The Thirsty Earth*

there are rare and uncertain rains, are plants which are adapted to the very trying conditions. The seeds are hard and dry, and will live for years in the dormant condition. Some of the plants themselves are hard, dry, and leathery, and the leaves are often coated over with wax, or resin, or gum. These plants are adapted to the excessively dry climate, many are apparently dead, but spring into rapid, vivid life when an occasional shower of rain comes to revivify them. The leaves are necessarily small, so that there is little loss of moisture by transpiration, and the roots go down to astonishing depths in search of ground water. Some plants survive by means of bulbs or tubers, which are buried in the ground, of course, and in which water is stored. In some parts of the desert, especially in depressions between the long barren ridges, a well may give a permanent supply of water and a fertile *oasis* may result. Or a river may come from distant snow-clad or rainy mountains and may bring life to a narrow belt of country which would otherwise be hopeless desert. The Euphrates, the Indus, and especially the Nile, thus cause long fertile belts in the deserts, and show the natural fertility of the soil when supplied with water under the hot sunshine. In these oases and in these hot alluvial valleys palms grow to perfection, and under their shelter cereals such as maize, wheat, and barley, peas, beans, and lentils, and tropical and sub-tropical fruits, are grown. The date, fig, orange, lemon, pomegranate, melon, and olive are some of the better-known fruits produced under these conditions.

Deserts of this type occur in Mexico and the south-western States of U.S.A., in South America (where the desert of Peru resembles that of Mexico and Lower California), in north Africa and Arabia, in south Africa, in north-western India, and in Australia. It will be

noticed that the deserts extend beyond the tropics in both hemispheres, and gradually give way to more fertile conditions in latitudes 25°–35°

Intermediate Tropical Types.—It is to be expected that the transition between the types described above will not as a rule be abrupt, intermediate modifications connect, for example, the summer rain type and the semi-desert type The dry season gradually lasts longer, and the annual rainfall comes in a much shorter time and is far less in amount There are two modifications which deserve especial mention, the savana type and the tropical thornwood type The latter is the drier and merges into semi-desert, having seven or eight months of dry weather and a wide range of temperature The former is hotter and has more rain, but the conditions do not produce forest growth

The *Savana* is typically developed in South America, north and south of the great forest belt of the Amazon It is also found in Africa, both north and south of the equatorial belt, bordering the Sahara and the Kalahari A modified savana divides the rainy belt of north and east Australia from the very dry interior

In Africa, east of the Congo basin, a belt of plateaux stretches from the northern to the southern tropic The equatorial forest is only developed in the river valleys, the plateau land is too high for the dense forest growth normally found in those latitudes The vegetation is therefore of the savana type, and the southern Sudan may be taken as an example The grass grows in clumps or tufts, reaching from 6 to 15 feet high, and between the tufts are patches of bare, dry soil It is thus a grass land in the main, but here and there are patches of trees, increasing under favourable circumstances, such as in the valleys, to the dignity of forests The savana may thus be described as tropical park land

The savana is suitable for cattle-rearing, the plains of the La Plata basin are among the most famous cattle regions in the world Cotton, sugar, coffee, and tropical fruits such as the banana and pineapple are the typical crops Cotton is being grown on the irrigated and naturally-watered parts of the Sudan in increasing quantities Rice succeeds well in the lower part, where there is obviously an approach to the wetter conditions Maize, wheat, and barley are grown, often by the aid of irrigation

The *Tropical Thornwood* type of Brazil and some parts of east Africa is mostly barren and useless, and can only be made available for man by boring for water and subsequent irrigation Maize, sugar-cane, and cotton are now grown in reclaimed parts

Warm Temperate Lands

These lie, broadly speaking, between the tropical deserts and about 45° latitude, but of course there is no hard-and-fast line As before, four main types may be distinguished

(1) The Western Warm Temperate, or Mediterranean Type
(2) The Eastern Warm Temperate, or China Type
(3) Warm Temperate Plateaux
(4) Warm Temperate Continental Lowlands

Western Warm Temperate Type — Mediterranean Type—The climate of the Mediterranean region was discussed in the preceding chapter, it is the climate which largely determines the character of the vegetation The dry warm summers and the mild rainy winters are the dominant features of the climate, and the plant-life is adapted to these conditions The winters are mild enough for plants to continue in bloom where growth would be suspended in winter farther from the equator.

The vegetation is at its best in spring, when very rapid growth takes place in many plants whose activities are to be suspended in the hot, dry summer After this comes the summer, which is the period of comparative desolation , the grasses turn brown, the plants with bulbous roots die down, and the seeds of annuals lie dormant until the autumn

The forest trees vary with the rainfall , where it is wetter, walnuts and chestnuts are common , but in the more typical Mediterranean lands, where it is drier, evergreen oaks and similar trees occur in scattered and open glades

To survive the trying summer drought the trees have hard polished leaves, or small spiny ones In most cases they are evergreens, with small leaves either so specially protected that they will not lose much moisture in the summer, or evergreen so that they may take in carbon dioxide during the winter Many of the plants have hairs or spines on their leaves, no doubt as a protection against grazing animals, especially the goat Lavender, rosemary, laurels, and brooms are typically Mediterranean shrubs, all specially adapted to live through the trying dry season [1]

The holm oak of the Mediterranean is an evergreen for the reason mentioned above , there are other devices to prevent excessive loss of moisture due to perspiration , the wood of one kind of evergreen oak is protected by the thick bark with very close pores which is so well known and widely used under the name of cork

Evergreen conifers with needle-like or scaly leaves are among the important trees of Mediterranean regions The famous cedars of Lebanon are of course within the eastern Mediterranean province The forests of cedar and fir in California are also well known The Cali

[1] See note at end of this chapter

fornian "redwood" pine is a characteristic tree. The giant firs of Washington and California are other examples; these celebrated big trees belong to species of the genus *Sequoia*, different from the Californian redwood fir. The giant eucalyptus trees of Australia occur in similar latitudes, though not under Mediterranean climatic conditions only.

The grasses of the Mediterranean climatic regions are not the rich succulent grasses of the wetter cold temperate regions; hence cattle are not reared in anything like the same number. Some of the grasses are much sought after for paper-making and for plaiting into baskets and bags; the best known are the esparto grass of Spain and the alfa grass of North Africa.

The cereals do well in the Mediterranean regions, especially where sufficient water is supplied by irrigation, maize, wheat, and barley being grown in large quantities. These regions are perhaps most famous, however, for their fruits, which include fig, orange, lemon, apricot, and peach. The vine is everywhere cultivated and its products as grapes, raisins, or wine are among the most important sources of wealth. The olive tree is the most characteristic tree of this climate; its deep roots, its small, evergreen leaves, and its gnarled trunk, branching low down, are all adaptations to the hot summer and the mild rainy winter. Olive oil is therefore a characteristic product also, and plays the part taken by butter in cold temperate regions, in addition to many other uses. The mulberry is also common, and silk is therefore one of the important products.

All the regions which have the characteristic Mediterranean climate now produce many of these plants; and there has been a remarkable interchange of useful plants. The Mediterranean itself, California, Middle Chile, South Africa, and South and West Australia all

contribute a quota of these characteristic plants to the wants of man For example, a Victorian fruit farmer whose fields are fertilised by irrigation from the Murray may produce Mediterranean oranges and lemons, Californian apricots, and raisins dried from the grapes of vines introduced from Europe The prickly pear of California is now very common in southern Europe The sumach shrub of Sicily—so important in dyeing and tanning—has been successfully introduced into South Africa, and many similar examples from the plant world might be given The mohair goat of Asia Minor thrives in Cape Colony, and its wool or hair is now an article of export from that colony

Eastern Warm Temperate Type — China Type — The lands of this climatic type receive summer rains, and the winters may be dry and cold, thus the climate is often somewhat extreme, though, as was pointed out in the preceding chapter, there is great variation in this respect The forests contain many plants of great value The yellow pines from the South Atlantic and Gulf States, the Georgian white pine, the Virginia cypress, the cedars of Formosa, the walnuts, chestnuts, sycamores, and oaks are some of the valuable trees There is a certain amount of overlapping between the Mediterranean and China type, but the forests of the latter are richer

Among shrubs and smaller trees of economic importance are kauri gum, camphor, cinchona, yerba maté (Paraguay tea), tea, and the mulberry Cereals include maize, wheat, and millet, sugar-cane, rice, indigo, tobacco, and the opium poppy are other plants which are produced in these lands The bulk of the cotton of the world is grown in the south-eastern United States, which are typical eastern warm temperate lands Ramie fibre, the fibre of a nettle, is a product of these

warm-temperate lands It seems likely to become a more important textile fibre in the near future

Warm Temperate Plateau Type—As we pass from the eastern Mediterranean across the plateau of Asia Minor to Persia we pass from the typical Mediterranean to the plateau modification The rainfall is usually much less and the climate is more extreme Forests only occur in the occasional valleys, and even there vegetation is not very luxuriant Irrigation from mountain streams is relied on to give fertility, and cereals, cotton, tobacco, and such fruits as the peach, fig, apricot, and almond are grown Maize has been grown very successfully on the plateau of Utah by careful use of surface moisture, and the experience gained there is being applied in South America, Africa, and Australia

This type includes the Iran Plateau, Asia Minor, parts of Arabia, the southern Kalahari Plateau of South Africa, the High Veld, the Great Basin of North America, the higher Mexican plateau north of the tropic, the higher lands of Argentina, and the plateau of Central and West Australia Much of it is obviously desert and very slightly productive

Warm Temperate Lowland Type—The Pampa Type—This has essentially a low rainfall, with an extreme climate It passes in most of the continents gradually into the cool temperate lowland type Taking the warm temperate and cool temperate lowlands together for convenience, and remembering that the summers of the former are often very hot, we may note that these are the dry grass lands of the temperate zone There is usually a severe and dry winter with a mild and moist spring The vegetation is uniform over great distances, and forests are rare The tougher, drier grasses can stand the dry, warm summer, and are different from the grasses of such regions as Britain.

The soils are not necessarily poor, but the rainfall is too scanty for timber growth, with the help of irrigation, maize, wheat, barley, and sugar beet can be grown, maize only in the warmer parts however Stock-raising is a great source of wealth on the drier parts The prairies of North America, the Pampas of South America, the Steppes of Russia, the Veld of Africa, and the Great Karoo are the typical temperate grass lands The High Veld is a high plain, and passes into the warm temperate plateau type

The Cool Temperate Lands

It is again possible to distinguish four types of plant associations broadly, but it will be noticed that the differences between warm temperate and cool temperate marginal lands is more pronounced than that between the continental lands of these types The four divisions are

(1) The Western Cool Temperate Type—British Type
(2) Eastern Cool Temperate Type—Laurentian Type
(3) Cool Temperate Plateau Type
(4) Cool Temperate Lowland Type

The cool temperate lands form a belt across the northern continents, but in the southern hemisphere only the extreme south of South America, Tasmania, and South Island, New Zealand, fall within this group There are no African cool temperate lands except those due to elevation The characteristics of all these lands are cool summers, and cool to cold winters There is a great contrast in seasonal range between the marginal lands and the lands distant from the sea and the greatest ranges of temperature known occur in the lowlands of cool temperate type

Western Cool Temperate Type—British Type—This is characterised by mild winters and cool summers, and prevalence of westerly winds The range of temperature is low, not more than 25° to 30°, and rain falls at all seasons (page 292) There are no deserts possible under such conditions We need to consider only the forests and grass lands There are two types of forests, the deciduous and the coniferous The former occurs in the warmer, milder parts where the winters are not so cold The trees resist the winter by shedding their leaves The commoner trees are the oak, beech, ash, sycamore, horse-chestnut, elm, and lime, and the smaller shrubby trees such as the willows, aspens, alders, and rowans, which flourish under less favourable circumstances than the larger deciduous forest trees Where the winters are colder the deciduous forest gives place to the *taïga* or coniferous forest This occurs on the higher lands and towards the interior The coniferous forest occurs on all the highlands of central and western Europe, and stretches across Eurasia as a belt, narrowing in the middle of the Continent between the tundra and the steppe of the continental interior It also covers vast areas in North America It is essentially a sub-arctic forest adapted to a cold and moist climate The wealth of timber obtained from both deciduous and coniferous forests of the western cool temperate region is very great, and a vast lumbering industry depends upon it in Scandinavia, Western Russia, and British Columbia From the coniferous forest, in addition to timber in various forms, wood-pulp for paper manufacture, acetic acid, wood-alcohol (impure methyl alcohol), and wood tar are obtained in enormous quantities

Eastern Cool Temperate Type—Laurentian Type—As was explained in the preceding chapter, this is

characterised by cooler winters and by a greater range of temperature The coniferous forest comes down to lower latitudes and the deciduous forest trespasses on the warmer eastern type Thus the limit of coniferous forests at the sea-level is lat 45° in eastern North America, but is lat 60° in Scandinavia The *taïga* of the St Lawrence basin has nourished a vast lumbering industry for a long time now, the corresponding *taïga* of the Amur has not been so much worked, it still contains untold timber wealth

Cool Temperate Plateau Type—Altai Type—This is represented by the higher lands, such as Scandinavia below the snow-line, the higher parts of the Variscan European mountains, the Altai in Asia, and the Rocky mountains and Cascade mountains in North America, always, of course, well below the snow-line From above downwards the high mountains have snow-clad summits and upper reaches above the snow-line, below this vegetation of the tundra type, then grass lands followed by the *taïga* We may take the mountain *taïga* and the mountain grass lands as the natural vegetation of the cool temperate type

Cool Temperate Continental Lowland Type—The Siberian-Saskatchewan Type (see remarks on Warm Temperate Lowlands)—This also contains a belt of *taïga*, merging into prairie or steppe in the middle of the continent or southwards Where the rainfall is sufficient or the evaporation is checked by the low mean annual temperature, the *taïga* is developed, in the drier regions, and consequently where the seasonal extremes of temperature are greater, the forest gives place to grass lands, as in European Russia, Siberia, and Canada Such lands do not occur in the southern hemisphere

The cultivated vegetation of all these cool temperate

lands may be taken together Wheat may be cultivated almost throughout, except (*a*) in the colder northern parts, (*b*) in the wetter extreme western parts, and (*c*) in the driest parts of the continental interiors Barley and rye are also extensively grown, the latter being the main crop in the less fertile regions. Maize is not grown, as it requires a warmer summer. Potatoes for food, for starch, and thus indirectly for alcohol, are an important crop, and the beetroot now supplies enormous quantities of sugar The tree-fruits, apples, pears, and various kinds of plums, are grown in very large quantities, as are the berries, such as gooseberry, red and black currants Raspberries and strawberries may be grown almost throughout The drier parts are given over to stock-rearing, being too dry for cereals, or beetroot or potatoes

Arctic Lands

There are two different structural types, arctic lowlands and arctic highlands The latter may at once be dismissed, as the vegetation is negligible Arctic lowlands are known as *tundra*, and are found in Northern Eurasia and the extreme north of America There is a long severe winter and a short summer, in which daylight is almost continuous, but the intensity of the sunlight is of low value, as it falls upon the land at a low angle The plains are buried in snow for much over half the year , thus with the coming summer the surface only is thawed and shallow-rooted plants begin to grow The ground is permanently frozen at a depth of a few feet The only vegetation consists of mosses and lichens, with here and there dwarf bushes of crowberry, willow, birch, and bilberry. In favoured places, in the short summer, brilliantly coloured flowers burst into life in July, these include geraniums, willow herbs,

and saxifrage Trees are almost unknown, and there are no vegetable products of economic importance Observers in the temperate zone may readily study the tundra characteristics on the mountain slopes above the limits of coniferous forest This "alpine tundra" is well developed in the Alps and Pyrenees, and there are small patches of it in the higher, wilder moors of Britain, and in Canada and in the United States there is a well-defined zone on the western mountains, below the limits of perpetual snow

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Note on Garigue Vegetation

An impoverished type of Mediterranean vegetation is the *garigue* (pr gareeg, hard g) which is typically developed on the limestone lands of Southern France Drought-resisting small trees and shrubs are mingled with strong-smelling herbs and bulbous plants whose tubers and roots find shelter from the hot summer sun in the eroded cracks and joints of the massive limestone

CHAPTER XVII

PLANTS AND PLANT-PRODUCTS OF ECONOMIC IMPORTANCE

In this chapter the geography of the more important plants will be discussed, together with those immediate products derived from them which are of considerable economic importance This will again involve repetition, but there is some advantage in emphasising the plants themselves rather than the plant associations as was done in the preceding chapter

FOOD PLANTS

There are obviously several divisions or classes of food plants, the most important being undoubtedly the cereals, and these will be discussed first

THE CEREALS

These are cultivated grasses, the seeds of which are either eaten whole, or which yield flour or meal or other food-products They have undoubtedly been developed in their present form by man from " wild " grasses, most of the fundamental development having taken place before the dawn of written history Seeds of the more important cereals have been found in some Neolithic dwellings, and we also know that at the very dawn of Egyptian history (possibly the oldest history we

know) the art of growing and using the cereals was well known. Those of greatest importance are wheat, barley, oats, rye, maize, millet, and rice, and they will be discussed in the order named.

Wheat is the most important food grain, for from it is obtained the best flour, that is the flour which yields the most nutritive bread, as well as other valuable food-products. It is essentially a temperate climate grain, and its cultivation was first developed in all probability in warm temperate regions. It requires a moderately heavy soil—that is, a clay or a loam by preference—spring or early summer rains, and a fair amount of sunshine, and at least a fairly dry summer. It is grown in some part of every country which has a temperate climate, but there are now certain regions of the world which produce very large quantities. The thickly-peopled manufacturing countries of western Europe do not grow nearly sufficient for their needs, hence there is a considerable import. Especially is this the case with Great Britain, which now grows only barely 20 per cent. of its needs; but it is also true in a less degree of Belgium, Holland, and Germany. The best wheat-lands in Britain are in the East Anglian district and in parts of the south-east Midland Clay Vale and the Fenlands. France grows large quantities in the Paris Basin, the Biscay Basin, and the Rhone Valley. The Plain of Hungary, the Lower Plain of the Danube, and the Black Earth region of Russia yield enormous quantities. The Nile Valley produces wheat as a "winter" crop, and it is largely grown similarly in the lower valley of the Indus and the Punjab. Victoria, South Australia, and Western Australia grow increasingly large quantities. The largest wheat regions of the world are, however, the middle plains of North America and some parts of the plain of

Argentina In the United States the chief wheat-growing states are Kansas, North Dakota, Montana, Nebraska, Oklahoma, Washington, South Dakota, Idaho, Illinois, Minnesota, and Oregon, approximately in the order named In Canada, Saskatchewan, Alberta, Manitoba, and Ontario are the great wheat-producing provinces, in the order named The world's output of wheat in million bushels was as follows (in round numbers) in 1933

U S A , 528 , Soviet Union (?) 1016 , Canada, 272 , India, 352 , France, 360 , Argentina, 288 , Italy, 296 , Rumania, 120 , Australia, 184 , Hungary, 96 The world's total was estimated at 5200 million bushels , those given above account for over 3500 million bushels

It has been already mentioned that wheat is grown as a cooler season crop in Egypt and India , it is harvested in Egypt in about April and May, in the Punjab in March, and in the Lower Indus district in February The harvest in countries in the southern hemisphere comes, of course, towards the end of their summer , in January and February in Australia and the Argentine In the northern hemisphere it is harvested in May and June in the north of Africa and in China and Southern Japan , in June and July in the Mediterranean peninsulas, in July in Hungary, Rumania, and Southern Russia, and in August and September in England, Ontario, and Central Russia It will be seen that wheat is being harvested somewhere at almost every time of the year, so that the import of it to Western Europe could be almost continuous

It will be necessary to mention only very briefly the very numerous preparations of wheat other than flour *Macaroni* is made from wheaten flour in Italy

and the south of France The flour is worked into a dough with water and forced through gauges, just as in pipe-drawing *Vermicelli* is very similar, but is made into smaller rolls Macaroni and vermicelli are made from hard varieties of wheat grown in Italy and the other Mediterranean lands, and also imported from India There are numerous "pastes" made in Italy from wheaten flour, the latter being made into dough, rolled out into thin sheets, and then cut into small pieces Many preparations of wheat are now in vogue from Canada and the United States, most of them being put on the market under trade names, such as "Force," "Grape Nuts," etc An immense trade is now carried on in these partially cooked or otherwise prepared foods

It may be convenient to point out here that the United Kingdom and the Irish Free State imported 240 million bushels of wheat and 6 million sacks of flour (of 280 lb) in 1933 The wheat production in each of the years 1933, 1934, was about 60 million bushels

Barley —This cereal is grown over a wider range of climate than any of the other grain crops, for example, excellent barley is produced in the plains of North-Western India, and it is also grown as far north as 70° north lat in Norway This is not essentially a bread-crop, it is largely grown to be made into malt, which is used in the brewing of beer The barley grains are allowed to sprout, at this stage the starch in the grain has been largely converted into sugar, then the grain is killed by heating The sugar in the malt splits up into alcohol and carbon dioxide in the process of fermentation The greatest barley producing countries of the world in 1933 were U S A, 152 million bushels, Soviet Union, 344, Germany, 152, Canada, 64, Japan, 104, North Africa, 96

Oats—This cereal may be grown in regions where wheat does not produce very well, as it will stand a wetter and cooler climate Hence it is a more northerly crop in Europe and North America Oatmeal is baked into oatcake, and is also used for porridge and gruel Oats form one of the chief fodder crops, especially for horses Oats are now made into various prepared foods, and in these forms are now sold in immense quantities The chief countries where oats are grown are the following, in the order named United States, Russia, Germany, Canada, France, United Kingdom, Poland In the United Kingdom the weight of oats produced is more than equal to that of wheat and barley together Scotland and Ireland produce far more oats than wheat, the climate being more suitable for the former crop

Rye—This is essentially a northern cereal also, and is grown on poorer soil than wheat or barley It will also endure considerable extremes of climate Very little rye is now grown in the United Kingdom, though bread made from it was quite common among the poorer classes in the early part of the nineteenth century It is cultivated in the poorer sandy lands of Holland, Denmark, Prussia, Russia, and Southern Sweden It is there the chief bread-plant, and the so-called "black bread" made from it is the chief food of the peasantry Rye is grown as a fodder-plant, and for the sake of its valuable straw in the United States Rye-starch is prepared and sold in large quantities as *farina*

Maize—This is the crop always called "corn" in the United States In the British Isles it is often called "Indian corn" It is a warm-climate cereal, and its cultivation extends more widely into the tropics than the other cereals, but little into the cool temperate lands

It will stand neither great cold nor long-continued drought The climate of the British Isles is not warm and sunny enough, the dry summers of the typical Mediterranean lands are not suitable, except where irrigation can provide considerable moisture for the growing plants Where it can be successfully grown it is a paying crop, for it is very productive and yields far more weight per acre than either wheat, barley, or oats

Maize-flour or corn-flour is made from the grain, and is largely used in making blanc-mange, cakes, and puddings The meal is used for bread in some countries chiefly when mixed with rye meal In the United States a favourite dish called hominy—a kind of pudding—is made from coarsely-ground maize meal The whole grains are often cooked and eaten along with meat, much as the British use peas or beans The whole heads are cooked and are known as corn-cobs, and are a favourite dish in some parts of the United States Much starch is made from the grain, and from the starch in turn glucose (a form of sugar) is prepared This grain is also much used in brewing and distilling

This is the only cereal which has spread from the New World to the Old, and its name, Indian corn, is a reminder that it was cultivated by the original inhabitants of America

It is still cultivated in its own continent in enormous quantities, the valley of the Mississippi, with its rich soil and its moderate summer rains, suiting it admirably It is the great crop of the Central plain, between the wheat belt and the cotton belt There was nearly twice as much acreage devoted to maize as to wheat in 1928, and the yield in bushels was more than three times as great The remarkable part played by the United States in maize production may be seen from a

comparison of the whole world's output for 1933, given in quarters of 480 lb

Total for whole world	466,000,000 qrs
United States	272,000,000 ,,
Argentina	27,000,000 ,,
Soviet Union	22,000,000 ,,
Rumania	21,000,000 ,,
Brazil	23,000,000 ,,

The remainder was produced in India, Egypt, Mexico, Yugoslavia, South Africa, Brazil, Italy, and Hungary

Millet —This is the general name given to a number of grain-crops used almost exclusively in hot lands Perhaps the best known are Great Millet or Guinea Corn, and Spiked Millet The former is called *durra* in the Sudan, where it is largely grown. Both kinds are very largely cultivated in India as food crops A species of millet is grown in the southern United States as a green fodder crop

Rice —This is essentially the grain-crop of the hot lands It requires both considerable warmth and plenty of moisture, so that it does well in the hot equatorial lowlands and in the hot monsoon lands The plentiful summer rains of the latter climatic type in Asia suit it admirably, and that region is, *par excellence,* the rice land of the world The rich deltaic lowlands of Bengal, Burma, Siam, and China, and the hot coast-lands are the places where it is grown in greatest quantity Rice grows with enormous rapidity under suitable circumstances of soil and climate, and it yields a greater weight of grain per unit of area than any other grain crop Two crops are frequently obtained on the same ground in a year, so that rice provides a large amount of vegetable food in the regions where it is most freely grown It is significant

that these rice lands are the most thickly peopled parts of the earth's surface, and it is estimated that probably one-third of the human race uses rice as its chief food-grain.

This grain is not so rich in food value as wheat or oats or maize, and it is doubtful if the rice eating peoples possess the same stamina generally as the wheat and oats consumers of other lands; but probably other factors than the use of rice as the chief food are concerned with the difference. The Eastern peoples are gradually taking more to other food-grains as they adopt Western ideas in other respects. In addition to the use of the grain as food, much starch is prepared from rice. The straw of the plant makes a good fodder.

Rice is grown under circumstances similar to those of its chief home, in the Southern United States, especially in Florida and near the Mississippi delta, in the West Indies, Central America, in Brazil, British Guiana, British West Africa, and the Sudan. Just as varieties of wheat have gradually been evolved by selection which can stand a wetter climate, so varieties of rice have been evolved which grow in drier soil and in a somewhat cooler climate. The rice grown in drier and cooler lands now plays an increasingly important part in the world's output, especially in Egypt, Bulgaria, the Plain of Lombardy, and Spain.

Over 82 million acres were under rice in India in 1933, and the production was about 46,000,000 tons. The British Isles imported £520,000 worth of rice and rice flour from India in the same year. Siam exported nearly twenty million pounds worth in the same year, 1933. In Japan, about 8 million acres were under rice in 1931, and yet that country imported half a million

pounds' worth in that year, and three-quarter million pounds' worth in 1932 The Japanese imports mainly came from the more thinly peopled lands of Burma, especially the Irrawadi delta and the lowlands near the Salwen, and from Siam

LEGUMINOUS FOOD-PLANTS

There are a great number of plants which have their seeds enclosed in a long seed-vessel, after the manner of the familiar peas and beans Those which are used as food for either man or cattle are often termed *pulses* The chief are peas, beans, chick-peas or gram, soya-beans, and lentils All these seeds contain a relatively large proportion of nitrogenous food-stuffs, hence they are valuable foods

Peas are cultivated throughout the temperate zone, and they will thrive even in the cooler parts Canada and the United States produce the greater proportion of the peas which are imported into the manufacturing countries of Western Europe France, Belgium, Holland, Germany, all grow large quantities, in the British Isles they are grown in the Fenlands in East Anglia and the Clay Vale of Aylesbury, perhaps more largely than anywhere else

Beans—There are several varieties which are cultivated, some suited to colder climates, some only growing well in warmer lands The Mediterranean lands produce very large quantities, Egypt alone having nearly half a million acres under beans in 1928 Very large quantities of beans are imported into Britain from Egypt

Chick-Peas, or **Gram**, are grown in the Mediterranean lands and in India, where this and other pulses supply the nitrogenous foodstuffs which people in colder regions derive more from animal foods Gram is one of the

chief articles of diet in Spain, and the Spanish speaking countries of Central America also grow some quantity and import a good deal from the Mediterranean

Soya-Beans are chiefly grown in Manchuria, Japan and India These beans are widely used for soups and sauces, also as a food in India Their use as food is spreading in Britain and Germany The beans contain 30 to 35 per cent of oil, which is largely used in margarine manufacture, soya-bean cake is an excellent cattle food

Lentils.—These are grown in the same regions the Mediterranean countries and India, especially in the latter country, where again large quantities are consumed in place of animal food Lentil seeds are considered very nutritious Soups are commonly made from them in the cool temperate countries

ROOT CROPS

The chief of these used in temperate countries as food are the turnip, swede, and carrot The **Turnip** is probably a native of Europe, but its cultivation has spread into all the temperate lands It was known to the Greeks and Romans, it spread through Northern Europe in the Middle Ages, and was probably introduced into the British Isles in the sixteenth century There are now several varieties which have been developed to suit different soils and other conditions Like the other roots, it has not a high food value, but it is considered valuable as an anti-scorbutic

The **Swede**, or Swedish turnip, is cultivated very largely on the continent of Europe, and in North America, where it is known as *Rutabaga* This is the most valued of the turnip family, as it is not only more hardy but more nutritious than the common kinds of turnips Both the turnip and the swede are grown in the rotation of crops, usually following the wheat crop

There are two chief varieties of **Carrots**, the orange and the large white variety The orange carrot is the favourite in the British Isles, but the white and light yellow varieties are largely grown on the continent of Europe These three root-crops are used as vegetables, and also as fodder crops Turnips are often eaten on the land, the sheep or cattle being confined by hurdles to a limited piece of ground All three contain a relatively large quantity of sugar, but very little nitrogenous matter

Beet—There are several varieties of beet which are cultivated in temperate regions They have all broad leaves and long tap roots Mangel-wurzel, or mangold, is one which is grown as fodder for cattle in the sunnier parts of the British Isles The sugar beet is grown over a wide range in temperate regions in Central and Western Europe, in U S A , Canada, Argentina, and Australia It has now been successfully grown for some years in the British Isles, and in 1933 there were 364,100 acres under the crop, the leading counties being Norfolk, Suffolk, Lincoln, Cambridge, and Yorkshire About 500,000 tons of beet sugar were produced from the beets grown in England There were 20,000,000 acres under sugar beet in Europe in 1933, Russia having the largest acreage Germany, France, Czechoslovakia, Poland, and Italy were other important growers of sugar beet

Potatoes.—The potato is not a root, but an underground tuber , still, it may be conveniently studied at this point It is one of the plants which the New World has given to the Old, and its cultivation is now very widespread It is a plant suited to the temperate zone, and it thrives well in such different localities as Ireland and the Prussian plains, the one with a considerable rainfall and low range of temperature, the

other with a low rainfall and a comparatively wide range

There were over 1,100,000 acres (over 1700 sq miles) under potatoes in the British Isles in 1933, of which the Irish Free State had 365,000, and the production reached over 7,000,000 tons In the United States there were over three times the British area given over to this crop Canada had over half a million acres under potatoes in the same year, Ontario leading with 28 per cent of the total area Germany had 7,000,000 acres (11,000 sq miles), that is six and a half times the British area Russia claimed to produce about 50,000,000 tons in 1926 Potatoes are much in demand as a food, and they are also much used for the production of starch, and from the starch a good deal of sugar is made, and from this in turn large quantities of alcohol known as "potato spirit" "Brandy" is now largely manufactured from this source The starch and spirit industries are important in Germany and Holland

OTHER STARCHY FOODS FROM TROPICAL REGIONS

It has already been mentioned that starch is obtained from potatoes, rice, and maize All the cereal grains contain starch, but it is prepared from rice and maize more than from wheat and rye, and very little is prepared from oats The starch in these plants is, of course, a valuable part of the food they supply The mention of starchy foods leads to the consideration of certain other products from tropical regions, whose principal food-stuff is starch

Sago —This is obtained from the pith of various species of palm, all of which grow in equatorial regions The "sago-palm" of Malaysia is the best known and most important This grows in the equatorial lowlands, and yields a large supply of food with remarkably

little labour The trees are felled and split, and the starchy food washed out from the central parts The demand for sago has led to the systematic cultivation of this palm, and plantations of it are now worked in Borneo and equatorial South America The British Isles imported £400,000 worth of sago from Singapore in 1927 That port does most of the transhipping for all the trade of the Malay Peninsula and Borneo

Tapioca.—This is prepared from the tubers of the tropical manioc or cassava plant The plant is a native of Brazil, but its cultivation has now extended throughout most of the equatorial lowlands The tubers contain hydrocyanic or prussic acid in their original condition, and require to be washed with water, pressed and heated to get rid of that poison The granular meal derived from them after this treatment is the tapioca of commerce , if prepared in a slightly different way it is known as cassava powder Average tapioca contains about 83 per cent of starch, and the proportion in sago and arrowroot is not very different The British Isles import about 25,000 tons of tapioca and cassava per year, mostly from the West Indies and the East Indies

Arrowroot—This farinaceous food is obtained from the rhizomes or root-stocks of various tropical plants Jamaica, Bermuda, St Vincent, and the East Indies supply the bulk of the arrowroot which comes to the temperate countries of the west of Europe and North America

THE SUGAR-CANE

The sugar-cane is a tall grass from the root-stock of which stalks reaching 8–12 feet in height and 1–2 inches in thickness are sent up It grows under equatorial and tropical conditions and is widely distributed

It is cultivated solely for the sugar-juice obtained from the stem It is propagated by planting cuttings of stems which have buds at the nodes. The weight of sugar yielded varies from 7 to 15 per cent of the weight of the canes There has been a long and keen competition between the sugar-cane and the sugar-beet, but it has been by no means confined to methods of cultivation and extraction Fiscal legislation has played a considerable part Up to about 1886–88 the sugar-cane led, at one time quite easily, but owing to the bounty system on the continent of Europe the beet-root came abreast by about that time and then gradually went ahead In 1896 the sugar-beet supplied the world with 5 million tons of sugar, and the sugar-cane about 2½ million, that is, the sugar-beet supplied about two-thirds of the whole quantity The bounty system and protective duties, in Central Europe chiefly, seemed at that time likely to kill the sugar-cane industry By 1912 cane sugar had again forged ahead, and supplied 57 per cent of the world's supply The great new contributor was India, with nearly 2½ million tons The chief regions are now Cuba, Java, India, Hawaii, Porto Rico, U S A , Mauritius, Brazil, Australia, Fiji, Peru, and Natal The British Empire supplied 5 2 million tons of cane sugar in 1933 , the world's total was 17 million tons of cane sugar, and 9 million tons of beet sugar Partsch[1] wrote in 1903 "In a few years the United States will be the first sugar-producing country in the world, and will be powerful enough to set limits to the sugar-trade of other places" So far has this prophecy failed, that in 1933 the sugar output of the United States had reached no more than about two million tons from both the cane and the beet

[1] In *Central Europe*, "Regions of the World" Series

TEA, COFFEE AND COCOA

These are essentially products of hot lands, either equatorial lowlands, tropical savana lands, or lands of summer rains

Tea is especially a shrub of the monsoon lands of south-eastern Asia It has been claimed as a native of Bengal, and also as a native of the Chinese Empire A variety grows wild in Assam, which has been regarded by some as the parent stock from which all the others have been derived

The Chinese certainly cultivated it largely at an early date and made it known to Europeans, and China is still popularly regarded as essentially the home of the tea-plant Tea is a hardy plant, requiring much warmth, moderate moisture, and grows best in a well-drained soil Hence it succeeds best on the hill-slopes in the tropics Cheap labour is necessary to do the planting, picking, and subsequent handling, and it is chiefly on this account that the cultivation of tea has spread so little outside India, Ceylon, Java, Sumatra, China, and Japan, where labour is cheap

Tea-cultivation in India and Ceylon has increased enormously within the last half-century, and it has been carefully fostered by the Government Tea-planting has taken the place of coffee in Ceylon, the climate and soil having been found to be especially suitable to the tea-plant In 1882 Ceylon exported less than one million pounds' weight, in 1933 it exported 250,000,000 lb Tea-planting has also made some headway in Natal, Central Africa, the West Indies, Brazil, Australia, and Mauritius India, Ceylon, Java, Sumatra, China, and Japan produce the bulk of the world's demands The British Empire produced about 694 million pounds in 1933, most of it in India and Ceylon

The great consumers of the world's tea are the Chinese Japanese, the people of India, the British (at home and in the Colonies), the Russians, and the people of the United States The United Kingdom takes not far from half of the whole *export* of the world The import of tea into the United Kingdom in 1933 was over 500 million lb , the United States imported tea to the value of 29,000,000 dollars in that year

Coffee—The coffee plant is probably a native of north-eastern Africa, from whence its cultivation has now spread throughout the tropics It is obtained from the beans or seeds, which are enclosed in a seed-pod A warm and moist climate is essential, without excessive heat , the coffee shrub is therefore often grown under the shade of other trees Brazil now produces over three-fourths of the world's total The chief region lies between 20° and 24° S latitude, that is, almost on the southern tropic Rio de Janeiro and Santos are the great coffee ports of the Brazilian coffee lands, and Sao Paulo the great market The coffee-producing countries of the world are Brazil, the Dutch East Indies, Central America, the West Indies, Venezuela, British India, and Kenya It may be especially emphasised that coffee has not been listed as an export of Ceylon for many years The island was once famous for coffee, but in the prosperous years plantations were established rashly, and in unsuitable situations The ravages of fungi and insects have assisted in the failure, and tea has almost completely replaced coffee as a staple production The great coffee-consuming countries are the United States, Central Europe, and France

Cocoa (Cacao)—This is essentially a product of the hot equatorial lowlands, and its distribution is more limited than that of tea or coffee The fruit of the cocoa tree contains a number of closely packed seeds

The cocoa used for beverages is prepared from these seeds For the successful growth of the cocoa-plant the mean annual temperature should be about 80° F, and the dry season must be short It is produced in tropical America in Brazil, Ecuador, Venezuela, Jamaica, and Trinidad, in Southern Nigeria, the Gold Coast, and the island of San Thomé in tropical West Africa, and in the East Indian Islands Nearly half the world's output came from West Africa in 1933, with the Gold Coast as the world's foremost producer London is the greatest world market

Mate or Paraguay Tea—This is obtained from the leaves of a small tree or bush which grows in Southern Brazil and Paraguay An infusion of it is used in South America just as tea is used in English-speaking lands Prof Church disparaged its use very strongly, as it acts injuriously upon both the nervous and digestive systems

Fruits

Fruits of the equatorial region will be discussed first, and then those of cooler climates in succession

Equatorial and Tropical Fruits—These are very numerous, but very few of them reach temperate lands The difficulties of transport are as yet too great Residents and travellers in tropical lands often attempt to excite the envy of dwellers in cooler regions by descriptions of tropical fruits The chief of those which do reach countries such as the British Isles are the banana pineapple, coco-nut, and date

Banana—This requires a hot, damp climate It reaches as far north as Florida and Southern Japan, and as far south as Northern Natal and Southern Brazil The West Indies and Central America lead in the banana trade, and immense quantities are now shipped from thence to the British Islands, Canada, etc

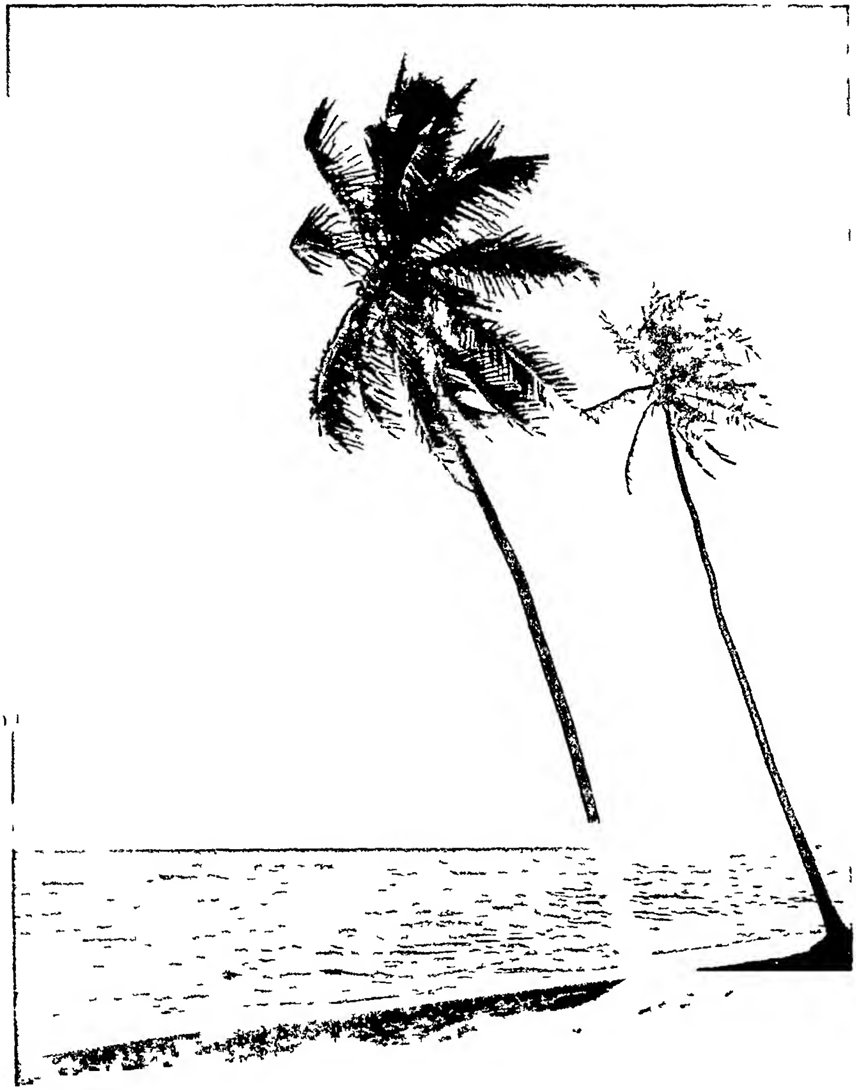

PLATE XX —COCO NUT PALMS CEYLON

PLATE XXI.—COTTON PICKING, SOUTH-EASTERN UNITED STATES

Pineapple.—This plant is a native of Brazil, and is now grown in tropical South America, Central America, the West Indies, Hawaii, Natal, and Queensland. It has been successfully cultivated as far north as Northern California. Large quantities are sent to Western Europe, chiefly from Jamaica and Central America.

Coco-Nut.—This palm is almost ubiquitous in hot lands, though it grows most luxuriantly near the sea, and especially on tropical islands. It is almost confined to the torrid zone, and to the lowest 2500 feet or so of the mountain lands of the tropics. Its uses are almost as varied as the tree is ubiquitous, the nuts as food, the milky juice, the timber and even the leaves, having a local importance. Much more important, however, is the production of *copra* and *coir*. The dried kernels, known as *copra*, yield an oil of which enormous quantities are used for burning-oil and in soap manufacture, for lubricating oils and as an edible fat; the *coir* or fibres which form the covering of the nut are used for making mats, etc. The coco-nuts which come to the British Isles are chiefly from Madras and Ceylon. It was estimated some years ago that at least forty million coco-nut palms were growing on the southern coasts of Ceylon. The British supplies of copra come from India, Ceylon, Straits Settlements, Java, Philippine Islands, Seychelles Islands, British East Africa, Zanzibar, British West Africa, West Indies, New Guinea, Fiji Islands, Samoa, and other tropical Pacific Islands.

Date.—The date-palm is a characteristic tree of the tropical thornwood or caatinga climate, and also of the desert. Its range is rather wider than the torrid zone, but its fruit does not ripen well in Italy or the Balkan Peninsula. Northern Africa, Arabia, Mesopotamia, Persia, and India are the chief regions for this palm.

The chief British imports of the dried fruit are from Arabia and the lands round the Persian Gulf There are other uses in addition to food, for the timber, leaves, and fibre are much used in the regions where it is grown, and a sweet beverage is made from the sap

SUB-TROPICAL AND WARM TEMPERATE FRUITS

There is, as may be expected, a good deal of overlapping of fruits in tropical, sub-tropical, and warm temperate regions, especially with fruits of the citrus family Fruits are common in the three types of warm-temperate climate, Mediterranean, Chinese, and Continental, and within certain limits the fruits indigenous to each type have been naturalised in the others The western type, with its dry summers, is rich in fruits, and a very great number might be enumerated Only the more important can be mentioned here

Orange—This is a native of the monsoon lands of south-eastern Asia, it has been claimed as a native of both India and China It was probably introduced into China at a very early date, and the Chinese have long cultivated the tree with great care It was brought from China to south-eastern Europe in the middle of the sixteenth century It has now spread to many tropical and most of the warm temperate lands The usual limit of its cultivation is about 37°–40°, but it reaches 43°–44° in the north of Italy The tree is evergreen, and its rich green glossy foliage can survive the dry warm summers As an illustration of the transference of fruits from one region to other similar climatic regions, the magnificent orange groves of Victoria and New South Wales may be instanced The plants were originally brought from Spain, and they flourish side by side with apricots introduced from California, but which probably came from Armenia originally Oranges

are exported in quantity from Spain, Italy (especially Sicily), Algeria, the Levant lands, the West Indies, South Africa, southern Brazil, and southern Australia In 1933 the United Kingdom imported from Spain alone oranges to the value of £6,000,000 approximately

Lime, Citron, Lemon—These are other species of the genus *citrus*, all characterised by similar fragrant or essential oils in the rind or peel, and all containing citric acid and potassium citrate in the fleshy pulp They are all grown in warm temperate and hot lands The citron was the first of the whole citron group to be naturalised in Europe, having been introduced by the Romans from Mesopotamia in the first century These fruits thrive in the West Indies, from which large quantities of lemons and limes are exported The limes of Montserrat and other islands are well known

Fig—The common edible fig is probably a native of southern Turkestan, and its cultivation has long been carried on in the countries bordering the Mediterranean, in Persia and Armenia, and especially in Asia Minor Smyrna is the chief port of export for figs They are successfully grown in Greece, southern Italy, and Spain Large quantities of dried and pressed figs are imported into the British Isles and other cool temperate lands

Mediterranean Nuts—Several nuts rich in oil and nitrogenous food-stuffs are grown and exported from Mediterranean lands The best known are *walnut, chestnut, filbert*, and *almond* Almonds are exported especially from Malaga, filberts from Barcelona, chestnuts from several Spanish and Italian ports These nuts are for the most part luxuries in the British Isles, but in the countries where they are grown they are important articles of food The hickory nut, well known in North America, resembles a small walnut

The last-named and the chestnut and filbert extend into the warmer parts of the cold temperate zone

The Vine—This belongs to the warm temperate lands, and extends slightly into the cold temperate regions Its northern limit is about 50° N It thrives best in Mediterranean lands with dry summers, but it is also grown in some eastern warm temperate lands The heavy summer rains of south and eastern China prevent the cultivation of the vine there for wine-making In Europe, the Iberian Peninsula, France, Germany, Italy, Hungary, and southern Russia are the chief regions for grapes California, eastern United States, Asia Minor, western South America, Cape of Good Hope, South Australia, Victoria, New South Wales, and North Island, New Zealand, are other vine-growing regions The grapes themselves, grapes sun-dried as raisins, and wines of various kinds are all important products of the vine Valencia, muscatel, and sultana raisins are dried grapes of varieties from which little wine is made Currants are small raisins from a variety of the vine grown in Greece, the Ionian Islands, Asia Minor, and Australia

The amount and quality of the wine obtained from grapes depends upon the nature of the soil, the climate, and, of course, upon the variety of grapes produced Methods of subsequent treatment of the grape-juice also count very considerably The result of the natural differences combined with differences of treatment is that almost every region has its own particular kind of wine, and certain kinds have been associated with the names of certain places from time immemorial The chief wine-producing countries are France, Spain, Portugal, Italy, Algiers, Palestine, Australia, South Africa, and U S A (California) The amount produced in Australia has increased considerably in recent years,

Plate XXII —Olives at Falicon, above Nice

[By courtesy of the Canadian Pacific Railway Co

PLATE XXIII —A CANADIAN WHEATFIELD

and in 1928 amounted to 20,500,000 gallons France imports cheap wines from other Mediterranean lands, and exports well-known brands of more expensive wines, her imports were twice the value of her exports in 1928

The Olive —The olive is *par excellence* a Mediterranean tree Originally a native, in all probability, of Asia Minor or Armenia, the tree has now spread throughout the Mediterranean lands, except Egypt The warm dry summers suit it admirably, but it cannot stand *cold* winters, and hence does not grow well on the open parts of the Plain of Lombardy Where there is good shelter from the cold north winds it thrives quite well, however, on the lower parts of the southern Alpine slopes

The tree is cultivated for the sake of the oil which is obtained from the outer parts of the fruit Olive oil is much used as a table oil, for cooking and preserving especially in France and Italy, and to a less extent in the other Mediterranean countries It takes the place of butter in cold temperate countries Italy is the greatest producer and exporter of olive oil, while France uses practically as much as it grows The British Isles import it from Spain, Italy, Turkey, Asia Minor, and Morocco Olive oil is used for soap-making, for cooking, for salads, etc

WARM TEMPERATE AND TRANSITION TYPES OF FRUITS
APRICOT, PEACH, PLUM, CHERRY, ETC

This group of stone fruits extends from the warm temperate into the cold temperate zone, where several varieties of these plums are successfully grown

Apricots are grown in Northern California, in North Island, New Zealand, and Victoria, all of which have a

modified Mediterranean climate The fruit can, however, be successfully produced in France and Southern Britain, but only with special care as to the aspect in Britain It is thus a transition fruit connecting the warm temperate and cold temperate zones, but thriving best in the former Its native country is not known with certainty, but the specific name, *armeniaca* given to it, from the old Roman name, suggests it came from the country south of the Caucasus, which has given so many useful plants to the temperate zone.

Peach.—This belongs to the same genus as the apricot and plum The apricot is *Prunus armeniaca*; the peach is *Prunus persica* The latter name suggests Persia as the native country, but this is by no means certain The peach is also a transition fruit, but it succeeds in the cold temperate lands rather better than does the apricot It is grown in France and the southern parts of Britain, but much more successfully in the United States, where it is largely grown and preserved in cans for export

Plums—The several varieties of the plum belong to the same genus, and are more essentially cold temperate plants, extending somewhat into the warm temperate zone Many kinds of plums—greengages, victoria plums, damsons, prunes, etc—are extensively grown on the continent of Europe and in different parts of the British Isles. Large-sized plums are grown in very great quantities in Serbia, and to a slightly less extent in Bosnia, Bulgaria, and Rumania Many of these are imported into the British Isles in the dried condition There is also a large import of plums from France and California Plums may be readily preserved, and both in this condition and fresh they form a favourite article of food

Cherry.—This is yet another plum, *Prunus cerasus*,

which is grown in both warm temperate and cold temperate lands The group therefore, which includes the apricot, peach, plum, and cherry, is characteristic of the transition from warm temperate to cold temperate climates, growing, broadly speaking, between 40° and 60°, though there is considerable difference of latitude in the different regions, as may be expected

Apples and Pears.—These belong to the same natural order of plants as the plums, and grow under broadly similar conditions of climate and soil They extend even a little farther into the cold regions, and in Norway apples are successfully grown very near the Arctic Circle They may, however, be grown in the warm temperate zone both under western, eastern, and continental conditions, though less successfully in the last, as at least a moderate rainfall is required Both are native in the cool lands of Western Europe, the common crab-apple, the probable parent of all the varieties of apple, being well known as a hedge plant in the British Isles They were known to the early Greeks, both being mentioned by Homer The apple is an exceedingly useful plant, both as a dessert and in many forms of cookery, the many forms in which it is served will be well known to every reader

These fruits are cultivated throughout the whole range of the temperate zone Western Europe, including the British Isles, Canada, the north-western United States, California, Victoria, Tasmania, and New Zealand, China, and Japan are the chief producers Both fruits are imported into the British Isles from the Continent, Canada, the United States, Australasia, and South Africa One of the best known regions is the Lake Peninsula of Ontario, which now produces enormous quantities of excellent fruit (*see* p 158)

SOME COOL TEMPERATE FRUITS

A number of useful fruits are more nearly confined to cool temperate lands, though their adaptability has led to their extension into the warmer lands to a somewhat smaller extent than in the case of the last group The red and black currant, the gooseberry, the raspberry, and the bramble or blackberry are well known and useful fruits, essentially plants of the cool temperate lands, and extending somewhat into Arctic regions The blackberry does not appear to be cultivated very much, though it would probably pay well for such treatment. The strawberry extends from the cooler parts of warm temperate lands right up to the Arctic Circle, the fruit grown in higher latitudes being preferred by many people The bilberry and cranberry extend well into the Arctic lands, and may be regarded as transition plants from the cool temperate to the Arctic They even grow under tundra conditions, Arctic tundra as well as Alpine tundra The fine luscious bilberries, which grow quite close to the snow and ice of the Alps, will be familiar to many a tourist.

OTHER VEGETABLE PRODUCTS

Spices and Condiments—Brief mention may be made of a number of food-adjuncts which illustrate the relation of vegetation to climate and soil. Most of the spices come from the hot lands, the monsoon regions taking first place As examples the following may be quoted *Pepper* comes from the Malay Islands and Indo-China, and is collected and marketed chiefly at Singapore *Ginger* is produced in the same general regions, where it is native It has now been introduced into British West Africa and the West Indies *Allspice*

(pimento) comes chiefly from the West Indies and British West Africa *Cinnamon* is produced in the Malay Islands, in Ceylon, and the West Indies *Vanilla* comes from Mauritius and Reunion and other islands in the Indian Ocean The Spice Islands (the Moluccas), as their name indicates, produce a number of spices, *nutmeg* and *cloves* come from there, and from Java and the West Indies Zanzibar produces 90 per cent of the world's demand for cloves

Spices played an extraordinary part in the early trade between the East Indies and Western Europe They were brought both overland to the Mediterranean and thence forward to the north-west, and also round the Cape The profits often made were enormous, as the spices were bought at very low prices in the Eastern market Of course the risks were very great, as not only were there the dangers from storms, and from rocks and shoals not mapped, but piracy was then very common

Tobacco and Opium—Though not foods, these narcotics may be mentioned at the close of this chapter

Tobacco—This is produced from several species of plants of the genus *Nicotiana*, all of which are natives of America Though probably of tropical origin, tobacco can be grown over a wide range of climatic conditions It is cultivated in tropical Brazil, in India and Java, and the recent attempts to grow it in Ireland are well known It is grown in large quantities between latitudes 45°–55° N on the continent of Europe Though of such wide range the tobacco obtained varies considerably according to the conditions of soil and climate

The United States produced about 1,410,000,000 pounds of tobacco in the normal year 1933 North Carolina, Kentucky, and Virginia were the three leading states The other chief tobacco-growing countries are France, Germany, Italy, Bulgaria, Turkey, India,

China, and Japan The United Kingdom imported tobacco (chiefly unmanufactured) to the value of over £20,000,000 in 1933

Opium —This is the dried latex of a species of poppy which is extensively grown in Egypt, Asia Minor, Persia, India, the East Indies, and China The Chinese demand for opium was formerly supplied mainly from India Both the growth and import are being rapidly diminished in China, the British Government having co-operated by legislation to reduce the contribution from India

Cinchona and Quinine —There are several tropical trees the bark of which contains a number of alkaloids, the most important of these alkaloids are quinine and cinchonine The bark itself is widely used medicinally under the name *cinchona bark* or *Peruvian bark* Quinine and compounds of quinine, such as the hydrochloride, sulphate, and some double salts, are freely used in medicine Quinine is valuable as a medicine in two ways, first as a specific antidote in malarial diseases, probably acting as a poison to the parasitic micro-organisms, secondly, as a febrifuge in intermittent fevers Cinchonine is not so valuable and reliable as quinine Many attempts have been made to produce the latter alkaloid synthetically, but, though its constitution is now understood, the production from simpler and cheaper compounds has not yet been achieved on a commercial scale Quinine, therefore, is still obtained from the bark of the various Cinchona trees These are natives of the tropical parts of the Andes, chiefly those between the equator and the southern tropic They flourish best on the slopes of the mountains between altitudes of about 2000 to 8000 feet, where rains are plentiful and there is copious sunshine The trees have been successfully grown in many other tropical regions,

and supplies of quinine and cinchonine are now obtained from a wide range of tropical lands Colombia and Jamaica, Mexico and Cuba, Southern India, Ceylon, Java and Sumatra, Philippine Islands, South Africa and Rhodesia are among the successful localities

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CHAPTER XVIII

PLANTS AND PLANT-PRODUCTS OF ECONOMIC IMPORTANCE—(*Continued*)

TEXTILE PLANTS

Cotton.—This is the most important plant-product outside the foodstuffs, from a commercial point of view, its growth is widespread, its uses so far-reaching There are three or four species of plants of the genus *Gossypium* from which cotton is obtained The seed-vessels of these plants are enveloped when ripe by tufts of white woolly fibres These fibres are easily "picked" from the ripe, opened seed-vessel

Cotton is grown in almost all tropical and sub-tropical regions, but its cultivation is most successful in the latter, or in elevated equatorial lands In India, Central Africa, and Brazil, for example, the cultivation is most successful on the plateaux, where sub-tropical conditions, of course, obtain The different species of cotton plant require a long summer, with moderate moisture, and a low range of temperature Equable warm temperatures, with no frost, produce the best results In the United States, still by far the greatest producer, the average temperature in the three most important months, June, July, August, is 76° to 82° There are copious summer rains, which rapidly diminish in quantity inland, and the chief areas of production are

some distance from the coast Texas, Georgia, Mississippi, Alabama, S Carolina, N Carolina, Arkansas, Oklahoma, Louisiana, and Tennessee are the great cotton-growing states Florida, for example, produced only 15,000 bales in 1932 against 4,445,000 bales from Texas It will be noticed that the dry western plains and the northern states are outside the cotton belt The limits are roughly 100° W and 38° N In India, the next great producer, the plant is chiefly grown in the regions fed by the monsoon rains, or in the well-irrigated regions of the north-west The temperature has a somewhat wider range during the important growing months, ranging from 75° to 88° In Egypt, cotton is almost confined to the delta and to those parts of Middle Egypt where water can be freely supplied by irrigation through the seven months of growth The average temperature at Cairo in the same three important months is from 83° to 85° The alluvial soil of Egypt is remarkably fertile, and this, combined with the climatic conditions, causes Egyptian cotton to be of very high quality [1]

The world's production of cotton amounted in 1932–33 to nearly 26,000,000 bales of 480 lb The United States contributed nearly 13,000,000 bales, India, 4,100,000, Russia (Turkestan and Caucasia), 1,800,000, and Egypt, 1,700,000 U S A may be expected generally to produce about 60 per cent of the world's total, and India about 16 to 20 per cent China produces a large amount of cotton for home consumption, chiefly in the valley of the Yangtse The amount produced in China is not known Great efforts have been made for many years to increase the output from different parts of the British Empire, the British Cotton-Growing Association having investigated conditions of soil, climate, and labour, and

[1] Anglo-Egyptian Sudan grows similar varieties

carried out extensive experiments in many colonies. The British Empire produced about 5,650,000 bales in 1928–29, that is over one-fifth of the world's known supply Outside India about half a million bales only were produced Uganda, Nyassaland, Southern Nigeria, Cyprus, and the West Indies were the chief contributors The United Kingdom imported raw cotton valued at £31,000,000 in 1932 and £37,000,000 in 1933, both years of "bad trade"

Flax.—This plant yields a variety of useful products The inner bark of the stem yields the fibre called *linen*, the shorter fibres, not long enough for weaving, form *tow*, which is used for rope and twine-making, the seed (linseed) yields an oil which is largely used in making paints and varnishes, when the seeds are pressed for oil a "cake" is left which is an excellent cattle food, under the name of *oil-cake*, the seeds when ground form the common linseed-meal used for poultices

Flax may be grown under widely different conditions of climate India, the colder parts of central and west Russia, the N.-E of Ireland, and the Pampas of Argentina, may be quoted as illustrating the wide variety of climatic and other conditions The plant is grown for different purposes, however, in these different regions In India, flax is grown chiefly for the seeds, and indirectly for the oil, the fibre of Indian flax is of little value In Russia the fibre is the more important product. In the United States the plant is grown almost exclusively for the seed

The chief regions for the production of flax are India, Russia, the United States, and Argentina The areas under flax in the countries named, in 1928 or 1929, were:

India . . .	3,124,000 acres
Russia . . .	4,300,000 "
United States . . .	2,720,000 "
Argentina . . .	7,000,000 "

In the British Isles the acreage under flax in 1928 was about 54,000 acres, of which roughly two-thirds of the whole was in Northern Ireland. In England alone there were 2600 acres where flax was being grown for the seed.

Hemp.—This plant produces a fibre similar to that of flax, only coarser and stronger; hence it is chiefly used for canvas, sailcloth, and ropes. It is grown over a wide range of climate, as in the case of flax. The three chief countries are Russia, Italy, and India. Russia produced 534,000 tons of hemp seed and 490,000 tons of hemp fibre in 1928. Italian hemp is of excellent quality, that of Piedmont being especially noted. Hemp is grown in India more for the sake of stimulants derived from it, of which the most important is *charas*, an intoxicating drug.

Jute.—This comes next after cotton and flax in quantity among the textiles of vegetable origin. It is a product of hot countries, the low lands of Bengal and Orissa producing the bulk of it. It needs a high temperature and moist conditions. Alluvial soils and rich loams suit it best. India had about 2,000,000 acres under jute in 1932 and produced nearly 6,000,000 bales of fibre.

There are several other fibres now produced in tropical lands, all of which are used for much the same purposes as hemp and jute. *Manilla hemp* is obtained from a species of banana grown in the Philippine Islands; *ramie* or *rhea*[1] comes from a species of nettle originally grown in China, but now grown in India, the East Indian Archipelago, Mexico, and North Africa; *hene-*

[1] Ramie fibre promises to become more important as an ordinary textile fibre in the future; at present its chief uses are in incandescent mantles, in the making of a special surgical lint, and in cloths made from mixtures of silk, artificial silk and ramie.

quen or *sisal hemp* is made from the thick fleshy leaves of an agave grown in Central America, the West Indies, Kenya, India, and the Philippines

Silk.—This is treated here because, though of animal origin, its production is dependent chiefly on the mulberry Silk is the fibrous material with which the caterpillar of the silk-moth encloses its cocoon. The growing caterpillar feeds on the leaves of different species of mulberry Silk is therefore produced in regions where the mulberry tree can be grown successfully It is essentially a product of subtropical and temperate regions The original home seems to be the eastern margin of the monsoon lands of Asia Silk has been known in China since long before the Christian Era, possibly about 3000 years before It is now produced throughout almost all China proper, but by far the greater proportion comes from the region between 30° N and 35° N This latitude may be compared with that of northern Italy and the valley of the Rhone, quite 10° higher in latitude The milder winters of the western lands, contrasted with the cold winters of China, are, no doubt, the explanation of this northerly displacement of the silk-producing region in western Eurasia The Middle Yangtse Valley, latitude 30° N, has winters only slightly warmer than the valley of the Po, latitude 45° N

Silk tissues were known and highly prized in Greece and Rome in the centuries immediately preceding the Christian Era, but the great writers, Aristotle and Pliny, had but the vaguest knowledge of its source and the method of cultivation Two monks brought eggs of the silk-worm concealed in a bamboo tube to Constantinople in about 550, and from that time the knowledge of its production and manufacture spread westward

Great Britain imported raw silk to the value of a

little over £1,300,000 in each of the years 1932 and 1933, U S A imported raw silk to the value of about £25,000,000 in the year ending June 30, 1933 Raw silk is usually about the first in value of the imports to U S A That country is by far the greatest manufacturer of silk tissues in the world

The production of silk in 1933 was approximately as follows [1]

The World's Supply	123 000,000 lb
Japan	98,000,000 lb
China	9,000,000 lb
The Near East	2,500,000 lb
Italy, France, and Spain	11,300,000 lb

The total world production has doubled since 1920

DYE-WOODS AND OTHER DYE PLANTS

These have for many years been much less important than formerly, their place having been largely taken by synthetic dyes produced chiefly from the coal-tar hydrocarbons This modern synthetic chemistry has almost entirely killed the growth of madder, and has adversely influenced the cultivation of indigo There are now signs, however, that there may be some reversion to the natural products

Indigo—This is by far the most important vegetable dye-stuff The plant from which it is produced is a native of south-eastern Asia, where it is still grown in largest quantity It has been successfully grown in tropical Africa, tropical America, and even in the regions to the south-east of the Caspian Sea The dye is obtained from all parts of the plant, which is cut down when flowering begins The plants are soaked in water

[1] As estimated by the Union of Silk Merchants in Lyon

and allowed to ferment for some time at about 85° F and the solid dye is obtained from the fermented liquid by evaporation Indigo is exported from India in the form of "cakes" The export from that country is greatest, followed by the Central American republics India produced 13,700 cwt in 1931, and 11,000 cwt in 1932

The woad of the ancient Britons produced a blue dye almost identical with indigo The cultivation of woad declined when the route to India was opened up, though many attempts were made to encourage its growth by restricting the import of indigo

Madder.—This plant was formerly grown in large quantities in Europe for the production of bright red and yellow dyes The dye-stuff present in extract of madder was prepared from anthracene, a cheap coal-tar product, in 1868 Since then the growth of madder has been on a very small scale, but as the vegetable dyes seem to be much more lasting than the synthetic dyes, there is some tendency to revert to the use of madder Much of the ground formerly under madder has been devoted to sugar beet, the requisite conditions of climate and soil being about the same for the two plants

Dye-woods.—These are obtained from the heart wood of certain trees growing chiefly in tropical countries The wood is usually imported into and sold in industrial countries in the form of "chips," the dye being obtained by boiling with water. *Logwood* is perhaps the most important It is grown in Honduras, Southern Mexico, and the West Indies Its dark-red wood yields an extract which is used in dyeing cotton, wool, linen, and leather, giving blue, brown, or black according to the mordant used along with it *Fustic* chips come from a tree grown in Nicaragua (Central America), a yellow dye is obtained from it which is

frequently used in conjunction with other dyes to give various shades of brown and orange *Brazil-wood*, a tree from Brazil, is now grown in other tropical lands, and yields a red dye A great many other plants yield dyes, but for a fuller treatment of the subject the reader must consult one of the manuals of dyeing Scores of vegetable dyes are used in India, Siam, China, and Japan, the very names of which are known only to the experts in the subject

Tanning Materials—Most of these are products of the vegetable kingdom Until quite recent years the only inorganic tanning material was common alum (potassium aluminium sulphate), but within the last fifty years chromium salts have come into regular use, and "chrome-tanned" leather has now displaced vegetable-tanned leather to a very considerable extent Only the more important vegetable tanning materials will be mentioned *Oak-bark* is the great tanning material of history, but *larch-bark*, and *hemlock-spruce-bark* are now serious competitors *Acacia-bark* is used in the Southern Hemisphere and is also imported to the industrial countries of the Northern Hemisphere

Extracts made by boiling oak-wood, chestnut-wood, hemlock-wood, and other woods under pressure with water, are now very widely used for quick tanning These are all trees of temperate lands An extract known as *quebracho* is obtained from the wood of a tree growing in Chile and northern Argentina It has a high percentage of tannins and is now very widely used for the tanning of cheap leathers for various purposes *Gambier* is obtained as an extract from the leaves of a shrub growing in the Malay Peninsula, Java, Sumatra, and Borneo, and is chiefly exported to Western Europe and the United States from Singapore Like quebracho extract, it has a high tanning value It

produces a very different leather from quebracho, however *Sumach* is a greenish yellow tanning material consisting of the young twigs and leaves of a Sicilian shrub very finely ground This shrub grows well under the conditions of the dry Mediterranean summer, and it has now spread into Tunis and Algeria, as well as to South Africa A very similar plant, *lentisk*, of somewhat inferior tanning value, is grown in Cyprus. It is often used to adulterate the more valuable and expensive sumach Genuine sumach produces soft light-coloured leathers, and is much used in the tanning of goat and sheep-skins for special purposes, especially when bright colours have to be afterwards used in dyeing the leathers It is also used as a mordant in cotton and wool dyeing There seems no reason why sumach should not be freely grown in Australia and New Zealand, where it could be used for tanning some of the lamb and sheep skins so plentiful in those countries

VEGETABLE OILS AND FATS

A large number of plants yield sufficient oil to pay for extracting In many cases the oil is extracted from the fruit or seed, but in some cases from the root Oil-yielding plants are found in both tropical and temperate regions, but far more is obtained from various plants growing in the hot lands Oils and fats are extracted by pressure or by solvents from a great number of plants, some of which enter largely into export trade, while many have a more local and limited use The most important and widely-used are the following olive oil, rape oil, ground-nut oil, cotton-seed oil, sesame oil, beech-nut oil, linseed oil, hempseed oil, castor oil, palm oil, cocoa (cacao) butter, shea butter, coco-nut oil, palm-kernel oil

Olive Oil.—The distribution of the olive has already

been discussed The oil is expressed from the pericarp of the fruit, and the best kinds are used chiefly as a table-oil for cooking and preserving The oil from Lucca in Western Italy is especially preferred for that purpose Inferior kinds are used in soap-making It is now largely adulterated with ground-nut oil and cotton-seed oil Italy produced 18 million gallons of olive oil in 1929

Rape Oil.—This is made from the seeds of different species of brassica, which are widely cultivated in Central Europe and in Northern India The seeds of *Brassica rapa* yield the variety known as *colza oil* Both kinds are used for lighting and lubrication

Ground-Nut Oil is obtained from the nuts of *arachis*, the ground-nut plant The pods bury themselves in the ground to ripen, hence the name ground-nuts It is a native of Western Africa or the West Indies, and is grown in both regions British West Africa exports large quantities, chiefly to Marseilles, where the oil is used instead of the more expensive olive oil The plant has been cultivated in India in recent years, and large quantities of the oil are now exported from there, over 3 million tons' weight of ground-nuts in shell were produced in India in 1933

Cotton Seed Oil—The distribution of the cotton-plant has been discussed already The oil is expressed from the kernels of the seeds after removal from the "shells" The kernels are crushed between rollers to form cotton-seed meal This is then placed in woollen bags, and submitted to hydraulic pressure at a temperature of about 100° C When the oil has been extracted from the seeds[1] there is left in the press a residue which is known as oil-cake, and which forms an excellent cattle food The oil is chiefly used for

[1] The process is the same for many other oil seeds

lubricating purposes and for soap-making, but considerable quantities of the refined oil are used to adulterate olive oil

Sesame Oil or Gingelly Oil—The seeds of a plant *Sesamum indicum* yield more than half their weight of oil It is cultivated in Egypt, Asia Minor, and India most largely, though it thrives in all the warmer climates The oil is used for lighting, and as a table oil in the East India had 5,400,000 acres under sesamum in 1932 and produced 465,000 tons of sesame-oil seeds

Beech-Nut Oil.—This is obtained from the fruit of the beech in the south of France, in the southern Carpathians, and northern Balkan regions, where the beech abounds It is used for soap-making, chiefly in France

Linseed Oil—This is one of the most important of the oils It is extracted from the crushed seeds of the flax plant, either by pressure while hot, or by such solvents as carbon-bisulphide or petroleum The crushed meal, after extraction of the oil, is an important cattle food Linseed oil is used most largely in the preparation of paints and varnishes, and in making oil-cloth and linoleum It is the best known of the drying oils, on exposure to the air it absorbs oxygen and becomes hard and dry It is also used for soap-making As was pointed out on page 378, flax grown in hot countries yields more oil than that grown in colder countries India produced 411,000 tons of linseed in 1932 Argentina now exports large quantities of linseed, and a further supply is exported from Russia

Hemp-Seed Oil is used for similar purposes, and is frequently used as an adulterant of linseed oil

Castor Oil.—This oil is obtained from the seeds of the castor-oil plant, *Ricinus communis*, which is probably a native of tropical Africa It is now grown in many tropical lands, India and Southern China being

probably the largest producers The British supplies of the oil come mostly from Bengal It is used in medicine and for soap-making in western lands In China and India it is a table oil

All the oils mentioned above are liquid at ordinary temperatures There are, however, many vegetable oils which are solid at the same temperatures, these are generally known as vegetable fats or vegetable butters There is, of course, no real difference, it is simply that the melting-points of the solid group are higher than those of the liquid oils The vegetable oils or fats now to be discussed are solid at ordinary temperatures

Cocoa (*cacao*) Butter—This is obtained from the seeds of the cocoa plant, *Theobroma cacao* It is a whitish or a yellowish semi-solid fat which is used in the manufacture of superior soaps The distribution of the cocoa plant has been mentioned in Chapter XVII

Shea-Butter—This is a yellowish fat or oil which is obtained from the seeds of several species of Bassia, a genus of tropical trees The chief regions are India and Central Africa The "shea-tree," or *Bassia Parkii* (from Mungo Park, the celebrated traveller), is a very important tree in the commerce of tropical Africa

Coco-Nut Oil—This is obtained from the coco nut, the fruit of a species of palm which, as pointed out already, is grown widely in the tropics The oil is got from the kernels, which are often dried and exported to the industrial countries under the name of copra This vegetable fat is widely used in soap-making, margarine-making, and for other purposes It is exported from Madras and Ceylon in large quantities

Palm Oil.—This oil is obtained from the fleshy outer covering of the fruit of several species of African palm trees The best known is the Guinea oil tree The oil

as it comes into commerce varies in consistency from soft butter to rather hard tallow It is used in soap and candle-making, in the tin-plate trade, and as a cart and carriage grease or lubricant West Africa is responsible for the largest supplies of this oil

Palm-Kernel Oil.—This oil is extracted from the kernels of palm-fruits, chiefly by the use of carbon-bisulphide It is quite different from the oil obtained from the outer covering of the fruit It is very similar to coco-nut oil in appearance, and is used for the same purpose, viz, soap-manufacture The kernels are chiefly exported from West Africa

GUMS, WAXES, ETC

Resin is the general name for a number of substances which exude from the stems or branches of certain trees, and which have the same general properties The best-known comes from the southern United States, where it is obtained from the "Southern Pine" It is the residue after the distillation of the *oil of turpentine* from the crude turpentine obtained from those trees The United States is the chief exporter of both oil of turpentine and resin Resin is used in soap-making, in the preparation of varnishes, and in paper manufacture

Kauri Gum is a resin obtained from a pine in New Zealand, or from deposits found in those parts of North Island which were formerly covered with forests of that pine

Many gums or resins are obtained from trees which grow in and near the warm temperate and tropical deserts Frankincense, myrrh, gum benzoin, gum arabic, gum acacia, gum tragacanth, and gum tragasol are among the best known

Camphor—This is a crystalline substance obtained

from a tree growing in the monsoon lands of south-eastern Asia, it is a native of China, Formosa, and Japan Camphor is found in all parts of the plant, but the greater part is extracted from the wood of the stem *Borneo Camphor* is obtained from the stem of a different tree which occurs in Borneo

Eucalyptus Oil and Gum —These are obtained from trees which are natives of Australia and in the south-eastern parts of the Malay Archipelago The oil exists chiefly in the leaves, the gum or resin in the bark Eucalyptus oil is now widely used in medicine Eucalyptus trees have been planted in Corsica, Sardinia, and the marshy lowlands near Rome, as it is believed they will counteract the malarial effects of the marshes It will be noticed that this is another example of the transference of trees from one region with a Mediterranean climate to another where the conditions are similar

Rubber —This is the solidified juice obtained from a number of tropical trees All the trees flourish in the hot, wet forests and monsoon The trees are tapped and the juice which runs out is allowed to stand The separated creamy-like substance is then heated with a small percentage of sulphur This "vulcanised" rubber is then available for a variety of purposes in the arts and manufactures and in everyday life When the first edition of this book was written, "wild" rubber, gathered from the equatorial forests of the Amazon, the Congo, etc, was the leading source, now plantation rubber has outstripped wild rubber completely The average production of rubber in the years 1930, 1931, 1932 (in tons) was, approximately

World production, plantation rubber—average 800,000 tons, of which British Malaya produced 400,000 tons, the Dutch East Indies 260,000 tons, and Ceylon 60,000 tons per year

World production, wild rubber—average, 32,000 tons, of which 24,000 tons came from Brazil

Great Britain imported raw rubber to the value of £3,000,000 in 1933, and U S A to the value of £12,000,000 France, Germany, Italy, Belgium, and Japan are also considerable importers of raw rubber

Gutta Percha and **Jelutong** are closely allied substances used for the same purposes, and prepared in the same way They are obtained from trees which are native in the Malay Peninsula, Java, and Sumatra

Balata is a similar pseudo-rubber obtained from British Guiana, Venezuela, and northern Brazil

TIMBER

An enormous international trade is now done in timber, though it forms such a bulky commodity, and is consequently somewhat expensive to carry The different vegetation regions of the world yield their different timbers, those of the tropics being of different nature and being used for quite different purposes from those of colder regions

Timber from Tropical Lands—Several hard woods, much in demand for furniture, are found in the hot, wet forests, and in the lighter summer rain and monsoon forests *Mahogany* belongs to tropical America, the chief supplies coming from Honduras, the lowlands of Mexico, Cuba, Hayti, and Jamaica *Green-heart* is an important timber from British Guiana *Ebony* wood is a hard, black wood obtained from trees grown chiefly in the forest of India *Rosewood* comes from trees found in the forests of Brazil *Teak* is a most valuable timber grown in India, Burma, and Java Rangoon is a great place of export Teak is a very hard wood, and it shows little tendency to "rust" even when continually exposed to moisture

Timber from Warm Temperate Lands Several important timber trees are grown in the warm temperate regions, both those of the western or Mediterranean type and those of the eastern or dry winter type In the Mediterranean region itself the walnut is an important tree, especially in the Balkan countries Boxwood is another important timber tree The cork oak is grown in Spain, Corsica, and on the western slopes of the Atlas The famous Cedars of Lebanon are, of course, in lands of Mediterranean type, but they do not contribute to the timber of commerce Both white cedar and red cedar are found in warm temperate lands, and in those which are transitional from warm temperate to tropical, such as the West Indies and Central America The famous "Gulf Pine" of the United States is exported in large quantities from Louisiana, Florida, and South Carolina The redwood and Douglas pines of California are also important timber trees From Australia there are obtained durable timbers such as that from the jarrah, a gigantic species of eucalyptus, and the korri (*kauri*), another species of the same genus Both furnish very hard timbers which are widely used, they will even stand immersion in salt water, and are used for the building of piers, etc The kauri pine of New Zealand is another important tree from these warm temperate lands

Cool Temperate and Transitional Lands—There are two types of forests, which furnish hard woods and soft woods respectively The hard woods come from the deciduous forests The oak, varieties of the elm, beech, and ash are among the most useful timber trees of the deciduous forests The more northern coniferous forests have their counterpart in the hilly parts of the warm temperate lands From these come immense supplies of soft woods The white pine, hemlock

spruce, birch, and Scotch pine are among the famous timber trees of the cool temperate lands. A vast lumbering industry is carried on in the cool marginal lands. Scandinavia, Russia, Eastern Canada, and Western Canada supply the largest quantities of timber together with the interior forests of Central Europe (more especially the Carpathians), and the slopes of the Rocky Mountains. The timber of the western marginal lands of south-western South America has not yet reached the European market in such large quantities as that from Scandinavia, Russia, and Eastern Canada. The forest of Amuria and Kamchatka are still practically untouched.

Materials for Paper-making, etc.—The immense quantities of paper needed in modern life demand a correspondingly large output of vegetable fibres from which the paper is made. The chief materials are timber from cool temperate lands and grasses from warm temperate lands. The woody fibre of spruce and pines is ground down to a pulp (wood pulp) and exported in the form of pressed sheets or boards; vast quantities of timber are indirectly used in this way. Esparto grass from Spain, the similar alfa grass of Northern Africa, and the delta grass from the plains of Rumania are all used in considerable quantities. In China and Japan the inner bark of the mulberry tree is used, and the paper made is very strong.

Rayon or Artificial Silk.—The manufacture of this new textile fibre is increasing year by year, and the amount now produced is estimated to provide about 3 per cent. of the world's total textile fibres; to that extent it is partly replacing and also partly supplementing the recognised fibres, cotton, wool, and flax. It is made by complex chemical processes chiefly from **wood pulp**, that from spruce being the favourite form of

pulp, a proportion is also made from linters and other forms of cotton waste The leading world producer is U S A, followed by Japan, Great Britain, Italy, Germany, France, Holland, Belgium, and Switzerland The names are in approximately the order of importance at the time of writing (1933), but that order is liable to change at any time

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Vol V *Rubber Tea and Cocoa*
Vol IX *Oils Fats Waxes and Resins*

CHAPTER XIX

GEOGRAPHICAL DISTRIBUTION OF ANIMALS: SOME ANIMAL PRODUCTS

ANIMALS are directly or indirectly dependent on vegetation, and the characters of the animals inhabiting a region are adaptations to the physical features and climate and the kind of plant-life found there There are, broadly speaking, four great regional types of land surface in this connection—forests, grasslands, deserts, and mountains, and in a brief survey of the "animal geography" of the world these simple divisions may be taken as the basis of the study

The present distribution of animals is not entirely accounted for by present environment, the migration of animals in the past, and consequently the distribution of land and sea in past geological ages, have exercised a directing influence on present faunas Thus Australasia contained very few of the higher orders of mammals when it first became known to the western world, probably the Australasian lands were separated from the rest of the land in the Mesozoic era, and very few migrations of the later-developed animals have reached it since that time South America contains a peculiar animal assemblage which inhabits its very varied lands from the hot, wet selvas to the southern pampas of Argentina The development of animal life has long proceeded on lines of its own in that continent, with probably few migrations from other continents.

The influence of man has already made itself very

widely felt, the herds of horses on the American grassy plains are the descendants of those introduced by the early explorers, on the other hand, man has very nearly exterminated the magnificent herds of bison which inhabited the prairies of North America only fifty years ago Man has introduced many animals which have become exceedingly plentiful, the horses of South America, the rabbit of Australia, the wild pig of New Zealand, are conspicuous examples

The full study of the geographical distribution of animals, with the explanations drawn from the evolution of the present continents, including the adaptation of animals to their environment, and the study of the evolution and development of species, belong to Natural History, and especially to Zoology The chief animals of the different regional types will be briefly studied here, more especially those which are useful to man

Animals of the Equatorial and Tropical Forest—The animals which inhabit the equatorial forests show in a remarkable degree adaptation to the special conditions These special conditions include abundant food all the year round, with fruits ripening at all times of the year, no special seasonal differences of temperature are experienced The luxuriant undergrowth of the hot, wet forests is another of the special conditions There are consequently many animals which never descend to the ground, and they are specially adapted to their arboreal life The somewhat more open forests of the hot monsoon regions and of the tropical summer rains have more large animals which are ground dwellers, and they have also many "flying" animals Among the larger carnivorous animals are the tiger, the leopard, and the South American jaguar South America has many species of sloths and tapirs The tapirs of the Malay Archipelago are forest-dwellers Elephants are found in

the forests of Africa and the forests of the monsoon region of Asia The rhinoceros and hippopotamus are other mammals from the very extensive list of tropical faunas Lastly, the crocodiles and their allies may be mentioned, with the pythons and boas, and the great anaconda of the Amazonian forests

The anthropoid or man-like apes are all dwellers in the tropical forests There are at least four species the gorilla in the forests of West Africa, the chimpanzee in those of West and Central Africa, the ourang-outang of Borneo and the adjacent islands, and the gibbons of the mainland of South-East Asia They live chiefly on fruits, eggs, and young birds

It will be seen that the number of useful animals is not great, the elephants, of course, must be reckoned, but they are savana animals as well as inhabitants of the dense jungle

Birds are very abundant and exceedingly varied The gorgeous birds of paradise inhabit the forests of New Guinea and neighbouring lands, the bright-coloured macaws live in the South American forests, the crested cockatoos inhabit the north Australian tropical forests, and most of the parrots are tropical The brilliantly coloured humming-birds of South America are represented in all museum collections

Animals of the Tropical Savana and adjacent Deserts —The conditions are clearly quite different when we pass to those tropical regions which have a low rainfall The savana passes into the caatinga and then into the desert usually so gradually that in this connection they may be grouped together It is well to remember that the period of greatest growth follows or accompanies the rainy season (which may be short and irregular) In the long dry season plant-growth is almost suspended Hence the animals are such as can move

freely, are often fleet of foot, and they are frequently migratory

The lion is an animal of this region in Africa and Asia, its uniform colouring adapting it to parched and brown savana grasses and to desert rocks and sands The hyæna is a smaller carnivore of the savana The Cape hunting dog is a hyæna-like animal which hunts in packs, and preys upon the wild hoofed-animals, and the flocks and herds kept by man

The ungulates or hoofed animals are the most striking of the animals of the savana, especially of the African savana The antelopes are very varied and exceedingly numerous in individuals The giraffe is a beautiful example of adaptation, its long neck and fore limbs are obviously adapted to its habit of browsing upon the leaves of acacias and other savana trees It can only drink with difficulty and it can apparently go for months without drinking It is capable of very great speed to enable it to escape the attacks of its enemies, the carnivores The wild ass and the zebra occur mainly in the region transitional from the tropical to the warm temperate The camel is the highly specialised desert animal and is also transitional in type

Among the animals of the savana, the running birds show special adaptations to the conditions The ostrich is the best example, found in Africa, Arabia, and Mesopotamia Its long legs and neck enable it to see great distances, the long legs, and the reduction of the number of toes to two, enable it to run with great speed Like the giraffe it can endure for a long time without water The emu of Australasia is also a savana bird, feeding on the grass of the plains

Animals of Warm Temperate Regions—These regions are transitional between the tropical and the cold temperate and have no highly specialised assemblage of

animals It happens that many of the lands in this climatic zone are either mountainous or plateau, and there is consequently a considerable development of mountain faunas of different types So far as animals of economic importance are concerned it is especially the zone of sheep and goats rather than of cattle, especially in the Western Marginal or Mediterranean lands Sheep and goats can browse on the dried and sparse grass, or on the bushes which can resist the dry summer, but cattle fare much worse under these conditions The eastern marginal lands have more cattle, either the different breeds of the common or domestic ox, or the eastern zebus or buffaloes which are characteristic of the tropical as well as the warm temperate zones There are several species of goats found in the warm temperate zone, more especially in the drier Mediterranean lands, from which they have been acclimatised in similar regions in Africa and America For example, the mohair goat of Asia Minor does well on the plateaux of South Africa, just as the Spanish merino sheep thrives well in Australia The horse, the ass, and the wild ass are other animals which are either native or do well in the warm temperate lands, the wild ass being a characteristic animal of the drier Old World lands of this type This zone shares with the drier tropical lands the camel and dromedary as beasts of burden

Animals of the Cool Temperate Zone—The three chief vegetative types may be considered The *taïga*, the deciduous forest, and the steppe or prairie, the latter two overlapping into the warm temperate zone The animals of the *taïga* or coniferous forest may be dealt with first There are two broad groups of such animals those which are structurally adapted for forest life, such as the squirrel and the lynx, and those which roam over the prairie but visit the forest for

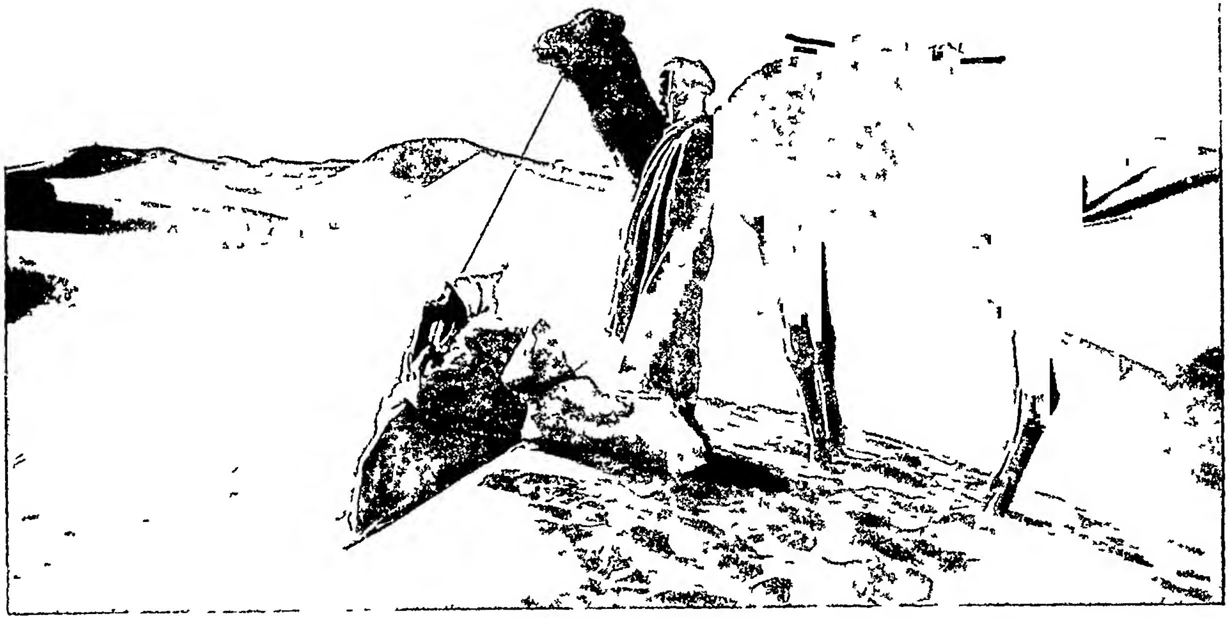

PLATE XXIV.—THE CAMEL, THE ANIMAL OF THE DESERT, AND ITS ENVIRONMENT

Note the structure of the sand dunes

Plate XXV — The American Bison (or Buffalo), Bos Americanus, Wainwright National Park

A typical prairie animal

shelter or food, of these, the fox and the wolf are examples

The important animals of the *taïga* belong either to the ungulates or hoofed animals, the rodents or gnawers, or the carnivores The ungulates include the wild boar and many varieties of deer The rodents include squirrels, the beaver, rabbits, and the Canadian porcupine The carnivores are chiefly bears, lynxes, the wild cat, and members of the weasel family

The deciduous forest is the home of similar animals to those of the coniferous forest, squirrels, beavers, wild boars, and bears making their homes there The wild boar of the deciduous forests of Europe still flourishes

The steppe or prairie is inhabited by special types of animals adapted to the physical conditions The climate is continental in character, that is, with wide ranges of temperature and a low rainfall, and the great plains are often swept by violent storms The rains generally fall in spring and summer and there is a wonderful growth of the prairie plants at this time If the rain fails there is corresponding scarcity There may thus be frequent alternations of plenty and famine, and the animals are migratory and social in consequence The prairie animals must also be swift of foot so as to migrate quickly from one region of plenty to another

Antelopes and gazelles are among the most numerous of the steppe animals In the steppes of western Asia the Taïga antelope occurs in thousands, and P Kropotkin quotes countless herds of antelopes in the eastern higher steppes Horses are typical steppe animals, no less than three species being native to the Asiatic steppes The prairie and steppe extend into the warm temperate zone, as has been already pointed out, and the horse as well as the camel overlap considerably the two sub-zones The great herds of horses on the

pampas of South America and the plains of North America are the descendants of horses introduced by the earlier conquerors of the continent. The bison takes the place in the New World of the antelope or horse of the Old World, and was originally exceedingly plentiful It has been calculated that there were between seven and eight millions in two vast herds, a northern and southern, in the great plains in 1871 Now there are a few thousands, specially protected, in the natural parks

The sheep is naturally more of a mountain animal, but it thrives well on the grassy prairies, and the vast flocks of Argentina and of the Darling Downs of Australia show how well it is adapted to the plains

The plains mentioned are in the warm temperate zone, but the sheep ranges into cool temperate plains in Siberia and Canada, and to the drier and less fertile plains of Europe

The wolf is almost ubiquitous in temperate regions, but it is more especially a steppe animal As is well known, it hunts in packs, preying upon the numerous ungulates and rodents of the great plains

Animals especially adapted to Life on the Mountains —Mountains usually show three fairly well-defined zones of altitude as regards their vegetation The lowest is the forest zone, the nature of which depends upon the latitude of the mountains In the tropics the lowest parts are clothed with equatorial forest, in the temperate lands the lower slopes may be rich in deciduous forests In any case conifers predominate in the highest forest zone Above the belt of conifers comes a treeless zone, with practically the character of a steppe; and last of all, if the mountains are sufficiently high, comes the Alpine zone, with tundra vegetation There are some interesting modifications in the nature of

these vegetation zones, which influence the special fauna For example, in tropical Africa the steppe zone is extremely dry, and becomes practically a semi-desert belt In plateau regions the steppe conditions may extend over a very wide area, as in the plateaux of Asia, and the lesser Meseta of Spain for example If the plateaux are very high then tundra conditions hold, as in part of the vast elevated plateau of Tibet

The special features of the fauna of mountains are the paucity of carnivores and the richness in ungulates Probably the two are correlated The ungulates are as a rule obviously well adapted to mountain conditions, they have great agility, are small footed, and have special protections against cold Sheep and goats are perhaps the most typical mountain forms, just as antelopes are typical of the steppe and savana Goats can thrive in drier and more barren regions than sheep, as they do not hesitate to eat even the spiny or hard-leaved plants of the high plains They can also climb and leap among the rocks with great ease

There are several "wild sheep" among the mountain regions of the northern continents The bighorn of the Rocky Mountains and the Pacific coast mountains ranges from northern Mexico to Alaska, its vertical range is so great that it is known on the lower walls of the Grand Cañon of Colorado, and in the Sierra Nevada and Cascade Mountains it lives at elevations of over 10,000 feet Its name indicates the unusual size of its horns, which are used in fighting It is a splendid mountaineer, and can leap from crag to crag with remarkable agility Its feet have a rubber-like pad beneath the sharp pointed hoofs to enable it to get foothold even on smoothly glaciated rock-surfaces

There is a very closely related species in Alaska, the Alaskan wild sheep, and both are so similar in

ground caribou, which occurs in large herds on the treeless plains to the west of Hudson Bay It migrates southward to the edge of the forest There is another allied species in America which has taken to the forest, and is hence known as the woodland caribou The true reindeer of the Old World has been introduced into Alaska by the United States Government, and under the care of herds-men from Lapland the animals are doing well

The musk ox is another ungulate of the tundra, and of the northern edge of the taïga, but it is limited to the New World Its distribution is not known with certainty, but it seems to be absent from Alaska, and plentiful in northern Greenland It combines some of the characters of sheep, goats, and the ox, and is peculiarly adapted to the extreme cold It is probably the hardiest of all herbivores

The presence of these large herbivores attracts the carnivores, which are, however, less highly specialised and may be regarded more as intruders from other regions The wolf occurs in both Arctic Eurasia and Arctic America, both in the tundra lands and in the Arctic higher-lands The Arctic fox is more thoroughly Arctic, and is widely distributed in both the Old and the New World

The polar bear haunts the margin of the sea Its large size, and its white or yellowish white colour, distinguish it sharply from other bears It lives on the seal and walrus, and haunts the drift and floe ice in search of its prey It seldom penetrates far inland

Animals from an Economic Point of View

A comparatively small number of animals are very important economically, and this aspect of the subject may be briefly treated here The chief animals whose

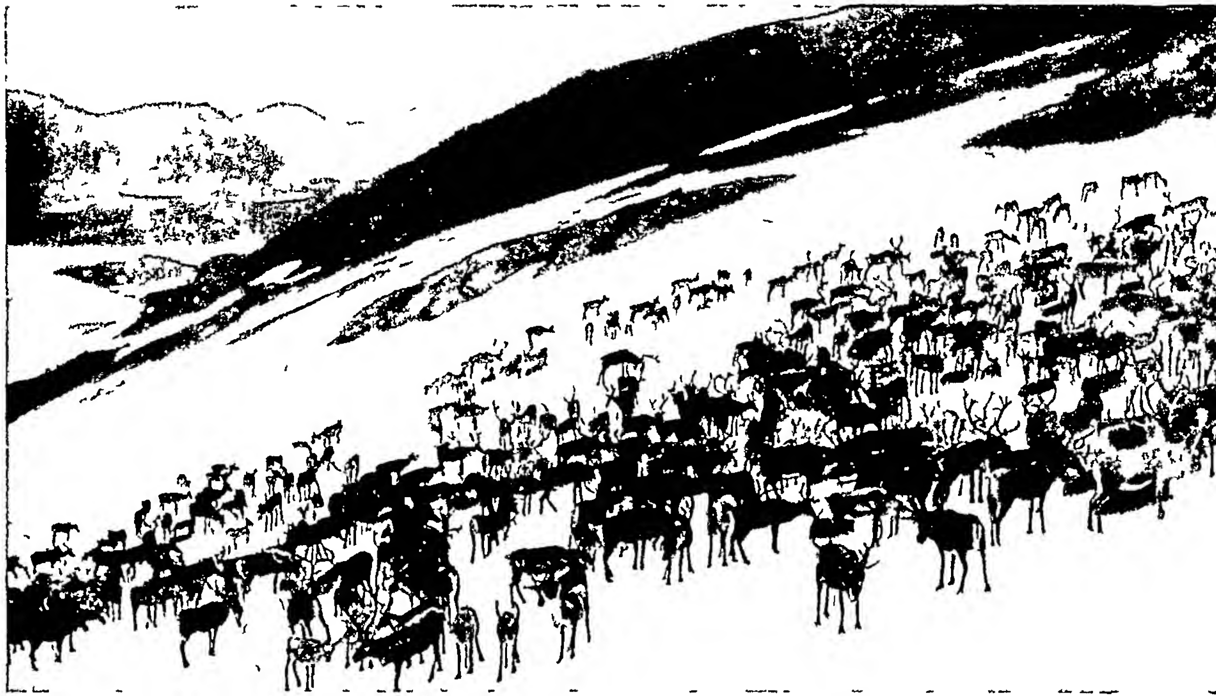

PLATE XXVI —CHARACTERISTIC ARCTIC UPLAND SCENE A HERD OF REINDEER NORTHERN SCANDINAVIA

products enter into commerce are cattle (in the wide sense), sheep, goats, camels, the reindeer, and the horse

Cattle are associated with civilised man almost everywhere, but there are interesting differences and limitations The Chinese keep few cattle except for draught purposes, as with their teeming population the land is considered too valuable for grazing The number of cattle in the Mediterranean countries is in sharp contrast with the number in countries like Denmark The following table, giving the approximate numbers of sheep, cattle, and goats in four European countries, is instructive

	CATTLE	SHEEP	GOATS
Spain, 195 000 sq miles	3 800,000 (19 5 per sq mile)	20 000 0000 (102 per sq mile)	4,700 000 (24 per sq mile)
Greece, 49 900 sq miles	900,000 (18 per sq mile)	6 920 000 (139 per sq mile)	4,900 000 (100 per sq mile)
Denmark, 16 600 sq miles	3 000 000 (180 per sq mile)	730 000 (41 per sq mile)	Goats not sufficiently important to be enumerated
British Isles, 121 000 sq miles	12 000,000 (99 2 per sq mile)	28,000 000 (231 per sq mile)	Goats not enumerated

The comparison of 19 5 and 18 cattle per square mile in the Mediterranean countries, with 180 and 99 2 per square mile in the Western Marginal lands, is an illustration of the difference of climatic conditions Milk, butter, and cheese have not assumed the importance in the Mediterranean lands that they have in north-western Europe

How widely spread domestic cattle have now become, and how well adaptable they have proved to varying

conditions, may be seen from the fact that they are reared in large quantities under such different conditions as obtain in Denmark and Egypt, the Siberian plains and the plains of Australia New Zealand butter now competes with Danish butter in the British markets, and both Russia and Australia are now contributors to the British supply Cattle may be successfully reared on the high African savana, and on the savana of the East Brazilian highlands The chief cattle-rearing regions of the world are India, United States and Canada Russia (European and Asiatic), Argentina, Germany, France, Hungary, the United Kingdom, Denmark, and Southern Sweden The north-west of India from Cutch through the Punjab to Kashmir is a great cattle region, the animals being used as beasts of burden, and the hides forming one of the staple exports of that part of India One million pounds' worth of hides and skins were exported from India to Great Britain in 1928 The great exporters of live cattle and of carcasses or prepared meat foods are the United States, Canada, Argentina, and Australia

The **Sheep** is the most numerous of the domesticated animals It thrives under a great variety of conditions of climate and food-supply, and can be reared in lands which are not suited to cattle The four products which sheep yields to man are all of great importance, though wool has often been considered as the primary object of sheep-rearing But in modern times, mutton, tallow, and sheep-skins contribute a very important share to the wealth of sheep-rearing countries

The effects of selection and of careful crossing of breeds are well seen in the increased yield of excellent mutton and other products from such sheep as those of New Zealand and Australia The Merino sheep was

developed in the Mediterranean countries, where the dry climate of the summer was peculiarly suited to it It was introduced into Australia about the end of the eighteenth century, and in New South Wales and Victoria sheep of the Merino breed produce an excellent wool, unrivalled for softness and lustre, and of long staple Merino sheep, however, yield indifferent mutton and quite second-rate skins, hence crossing with English breeds has been resorted to, especially in New Zealand A good wool, with excellent mutton, rich yields of tallow, and some of the finest sheep-skins in the world for the light-leather tanner are now produced from the New Zealand cross-bred sheep That dominion had 4,000,000 cattle and 29,000,000 sheep in 1932, and exported wool to the value of £6,000,000, and frozen meat to the value of £9,000,000 in 1931

The great wool-producing regions of the world are shown in the following table

Approximate total wool produced by the world in an average year,

3000 to 3500 million lb

Australasia	870,000,000 lb
Argentina	355,000,000 lb
United States	350,000,000 lb
Russia	330,000,000 lb
South Africa	260,000,000 lb
New Zealand	220,000,000 lb
United Kingdom	128,000,000 lb
Uruguay	125,000,000 lb

Goats have already been mentioned as being adapted to a drier climate They can browse where even sheep find it difficult to get sufficient food, and are not even prevented by the resinous coatings of the leaves and the spines of the Mediterranean trees Generally

speaking, the climate of the Mediterranean regions is drier farther east, and the relative importance of the goat increases From the table on p 405 it will be seen that Spain has four times as many sheep as goats, but Greece has only $1\frac{1}{3}$ times as many, and it is probable that if statistics were available for Asia Minor the goats would far outnumber the sheep The plateau steppes of Asia Minor are the native home of the Angora goat, the wool of which, known as mohair, is highly prized for its length, fineness, and silky appearance Angora province alone is said to have more than a million goats This is the breed which has been introduced into South Africa, and the mohair of Cape Colony is now a regular and important export, and threatens to compete seriously with that of Asia Minor

Farther east among the mountains of Armenia and in Persia and Afghanistan the goat is the most important domestic animal, both for its wool and its milk The skins of Persian goats are highly prized in the leather industry, and some of the best glacé kid is chrome-tanned Persian goat-skin The Kashmir goat of the upland valleys and enclosed plateaux of the Karakorum and North-West Himalaya is well known, and yields the bulk of the wool from which the famous Kashmir shawls are made Goat-skins are tanned in India and exported in large quantities It may be mentioned that both sheep and goats are used to some extent as beasts of burden among the highlands of Central Asia

The Pig may be briefly mentioned, confining ourselves to the domestic pig, which is probably a descendant of the wild boar of Europe, North Africa, and Central and Southern Asia Its usefulness to man, and its wide range, need no comment In China the pig is by far the commonest ungulate reared, and the large black Chinese pig is found

everywhere In Central and South-Eastern Europe it is estimated there are over 36 million pigs In the woods of Serbia and Bosnia they feed on the acorns and beech nuts of the vast forests In Western and North-Western Germany the pig is of special importance, especially on peasant farms and small holdings Westphalian hams are well known Germany had about 22 million pigs on an average from 1930–32 In the British Isles, perhaps more especially in Ireland, the fattening of pigs helps in the upkeep of many a small farm The number of pigs for the four years, 1929–1932, averaged roughly 4,000,000, that of Ireland being a little over a million (See also the table on p 405, Cattle and Sheep, etc) On the prairies south of the Great Lakes of North America pigs are fattened on maize, and various products are prepared and exported from Chicago, Cincinnati, and other towns in that region The United States had, on an average, about 54,000,000 pigs in the last four years Pig-rearing has not reached such great importance in Argentina, as the following number of domestic animals in 1930 census year will show Cattle, 32,000,000 , horses, 9,800,000 , sheep, 44,000,000 , pigs, 3,700,000

The **Horse** is the most widely used beast of burden in all the countries of Western Europe and in those lands the civilisation of which is derived from Western Europe Its native home seems to have been the steppes north of Persia and the plateaux of Central Asia , it was probably first made subservient to man there, and its use afterwards spread to the Semitic people of Arabia and Egypt about three thousand years B C The wild horses of America, so very numerous on the pampas of the south, are descendants of those introduced by the Spanish and Portuguese An earlier horse which had inhabited America had

become extinct before the discovery of the continent by Europeans

The **Camel** is especially the beast of burden of the hot deserts and the deserts of the warm temperate region There are two species of camels proper in the Old World, the Bactrian camel with two humps, a native of the same region as the horse, and the Arabian camel with one hump It is this species that is particularly the "ship of the desert" The camel is remarkable not only as a beast of burden, but its milk and flesh are both used The Arab also weaves much of his clothing and the material for his tents from its hair

The camels of the New World have already been mentioned (p 402) The wool of the alpaca was brought into prominence in England by Sir Titus Salt, and the big mills at Saltaire and others in the neighbourhood of Bradford are still connected with the manufacture of alpaca goods

The **Reindeer** is to the men of the cold deserts what the camel is to the men of the warm deserts it is their beast of burden, they use its milk and its flesh for food, and its hide, its hoofs, and its horns all minister to their varied wants

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SECTION D

HUMAN GEOGRAPHY

CHAPTER XX

MAN ON THE EARTH

THE antiquity of man is still a matter of considerable difference of opinion. Some authorities hold that he was in existence during the later Pliocene, and he certainly seems to have been very widespread in the early Pleistocene. His precise origin is still somewhat obscure, though it is pretty certain that he descended from some ape-like ancestor. He did not descend from any of the four man-like apes in existence to-day, nor probably from any animal quite like them. It is more probable that he and they are descendants of some common ancestor of Miocene times. Again, it is very likely that modern man is only one of several branches from the common ancestry, some proto-men having become extinct during the long period of evolution.

It would be very interesting if we could trace all the varieties or races of modern men from the ancestors of early Pleistocene time, but that is not yet possible. There is still a great deal of doubt and obscurity about the precise relationship of the men or proto-men of the earliest times. The remains of early man are so fragmentary and have come from such different regions, that it is not only difficult to correlate the deposits in which they occur, but it is difficult to indicate the relationship of the possibly

different types of men We have, therefore, to take modern man as we find him, and the varieties or races commonly accepted are founded on the characters of man as he is to-day, and have no true evolutionary basis Our knowledge of early man is chiefly derived (*a*) from his actual remains, (*b*) from his weapons and implements, (*c*) from a study of rock-shelters, pile-dwellings, mural decorations, "kitchen-middings," and some of his burial places Amongst the more famous finds of the remains of man, perhaps four stand out as most important There is a skull in the Provincial Museum at Bonn which was found in a loam in the Neanderthal through which flows the little river Dussel The Neanderthal skull was studied by Huxley, and has become one of the most famous of the remains of early man It is distinctly human in character, but of a low grade, and is regarded as being nearer to modern man than to any of the man-like apes In the loess deposits of the Neckar Valley, east of Heidelberg, a human jaw was found, which is now in the University Museum at Heidelberg This early Pleistocene relic also indicates a man of a more lowly type than most of the modern savages In far-away Java a skull and some bones were found in 1892 in strata which were at first thought to be Pliocene in age, but which are now regarded as Pleistocene This was named *Pithecanthropus erectus*, that is, ape-like erect man, and certainly indicates a low-grade proto-man, but still more man than ape About twenty years ago Mr Dawson found a skull and part of a jaw in some gravels of the Ouse, at Piltdown, in Sussex, and these have been studied and described by Sir A S Woodward and Mr Dawson They are regarded as remains of a proto-man or very primitive man, more lowly in type than any savages of to-day There are many more skulls and odd bones which have

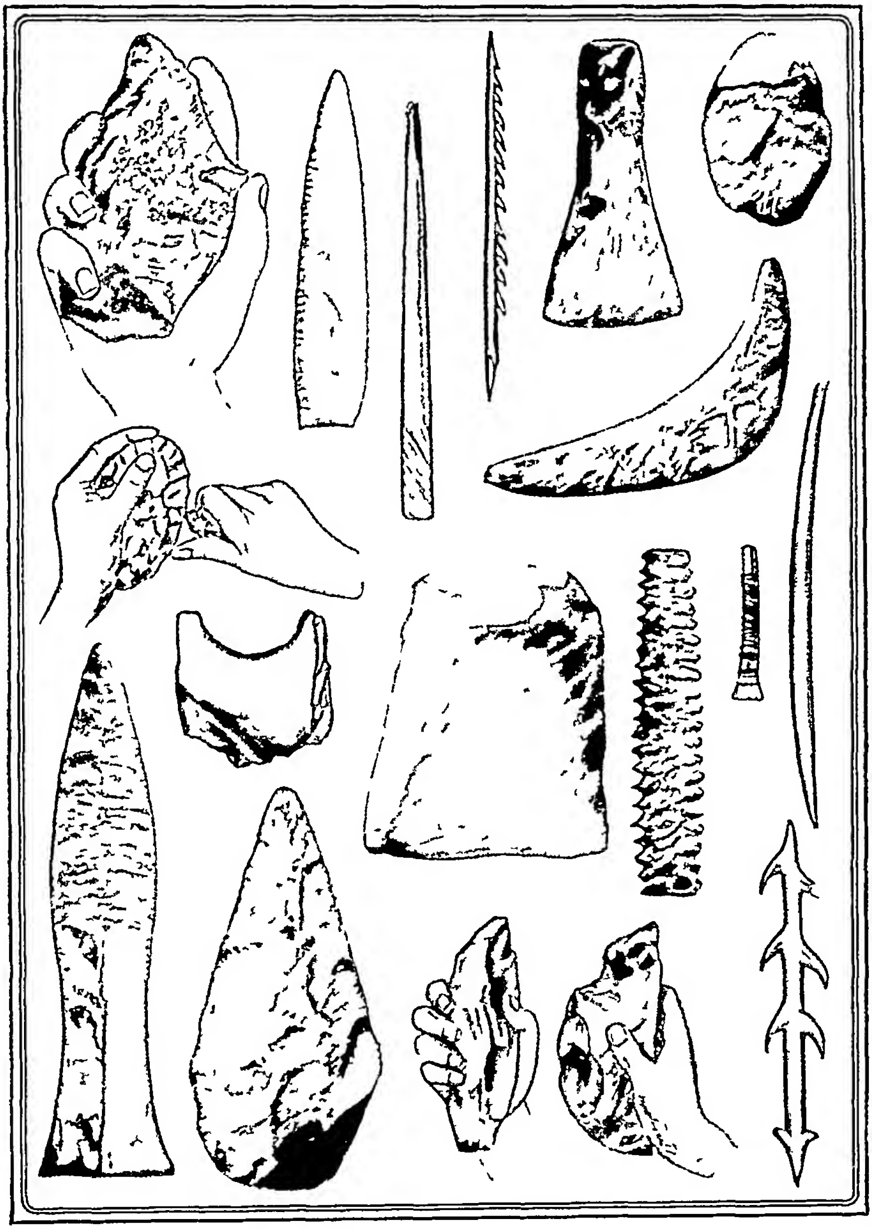

PLATE XXVII —IMPLEMENTS OF THE STONE AGE

From Specimens in the British Museum

been found, chiefly in Europe, where of course there has been the most thorough study of likely localities

In addition to the actual remains, the weapons and implements of men are found almost all over the north temperate and most of the torrid zone These are made of flint and other hard stone, and were fashioned by early man by knocking one stone with another, and so chipping them until they were of the desired shape Fine collections may now be seen in most museums In the earlier stages of man's evolution they were very rudely fashioned, but gradually improvement took place, certainly more quickly in some regions than in others, and in time smooth, well-made weapons became very common The ruder implements are characteristic of the Palæolithic Period (that is, the older stone age), the more perfectly made ones belong to the Neolithic Period (the newer stone age) There is of course no hard-and-fast line between the two periods, except in so far as students make an arbitrary division in any one district, and the transition from one to the other took place much earlier in some regions than in others It is not possible to distinguish absolutely the weapons and tools of the one period from those of the other Palæolithic man had certainly learned to grind his stones, and had anticipated some of the arts of Neolithic times All this, which would appear to follow from first principles, is fully borne out by extended observation and study Neolithic man was, of course, a great advance on Palæolithic man in general, he had better weapons and tools, he had acquired some control over fire, and he had begun to bury his dead

In north-western Europe, Palæolithic man was certainly a contemporary of the glacial period, he was almost certainly pre-glacial How far his migrations were influenced by the fluctuations of the ice it is

difficult to say. The glacialists are still far from agreed as to the number of interglacial periods (of milder conditions) that there may have been. Penck recognises five in the Alps, the late James Geikie claimed as many as eight, some of the Americans believe in three, and Lamplugh and Kendall, well-known English authorities, have argued for an undivided glacial period in Britain at least It may be remarked that there seems to be no reason why great fluctuations should not have occurred, say, in the Alps, while the ice maintained itself on the whole of Northern Britain It does not seem necessary to demand the same divisions of the ice age for all parts of the Northern Hemisphere

Whatever was the precise relation of man to the glacial period, he was a contemporary of the mammoth, the cave bear, the Irish elk, and other extinct animals He lived in North-West Europe when Britain was still a part of the Continent, and when the Rhine flowed over the North Sea plains Originating possibly in Indo-Malaysia, he spread to the rest of Asia, with which the land was then connected, and then to Northern Africa

From there he passed to Europe by the two land connections then existing, Morocco-Spain, and Tunis-Italy, and established himself throughout the early Europe After very long years Palæolithic man was replaced by Neolithic man, whether by conquest or by extermination and replacement is not known After the first settlements of Neolithic man there began the long rise in the knowledge of arts and of phenomena which is the measure of human evolution The North Temperate zone between the tropic and about latitude 55° was most favourable, and there he gradually reached his highest physical and mental development Primitive man of the tropics lagged behind, and the

peninsulas and islands of the Southern Hemisphere were too restricted to allow of great areas of different rates of development, that is of specialisation

The Neolithic age gradually passed into the age of metals, first of copper or bronze, then of iron These persisted for a long time, man slowly developing his powers of expression, first using mere picture-graphs, then conventional signs or ideographs, until phonetic signs led up to alphabets, and the historic age was fully established, which will persist through all future time With the dawn of history we find the great races of mankind fully established, and it is difficult to establish an unmistakable connection between the various men of Neolithic times and modern races, much more difficult again to work out the relation between Palæolithic men and any races of to-day

It is supposed that the Tasmanian natives, the last of whom died in 1877, represented most nearly Palæolithic man in build and manner of life They had been driven from Australia by the present aborigines, a race superior to them in intelligence They were hunters, their weapons were of stone or wood, they wore no clothes and had no houses, and they wandered about in search of food, and sheltered themselves from the winds by rude screens made of bark The Bushmen of South Africa are apparently very similar to other types of Palæolithic men, and in particular made the same kind of mural drawings Some of the later Palæolithic men were very much like the modern Eskimo

These Palæolithic men left their remains and weapons all over temperate Europe, but they died out or were exterminated, and the pastoral Neolithic folk took their places But even the relations of Neolithic man to the present race are not always clear, and we must

therefore briefly study the distribution of the present races of men as we find them, independently of any history

Four chief races are recognized, with many sub-varieties and groups of mixed origin These may have developed in the later Neolithic and bronze periods, when it is thought the general typical characteristics became somewhat settled The four commonly accepted races are (1) the Ethiopic or Negro, (2) the Mongolian or yellow, (3) the American or bronze, (4) the Caucasian or white

The **Ethiopic** or negro originally inhabited Africa south of the great deserts, and Madagascar, also Malaysia, the Philippines, New Guinea, and Australasia In modern times this race has spread somewhat over Northern Africa, and has been transplanted (chiefly as slaves originally) to the Southern United States, the West Indies, Central America, the Guianas, and the coastlands of Brazil

In this race the head is long, the nose broad and flat, the lips thick and everted, the eyes large, round, and prominent, the hair short, black, and woolly It is estimated that there are nearly 30,000,000 negroes in the New World, of whom about 10,000,000 are in U S A Education is making rapid progress among them, and many negroes now fill responsible positions in the United States, in the British dominions, and in Latin America

The **Mongolian** or yellow races originally came from the vast plateaux north of the Himalaya They have spread into Indo-China, Malaysia, China, Japan, Turkestan, Asia-Minor, Turkey, and Hungary, they have relatively short heads, and very small concave noses, thin lips, small oblique black eyes, and long, coarse, black hair They are mostly Buddhists or Mohammedans The Eskimos are considered by some to be an early

branch of the Mongoloid stem, somewhat akin to the Amerindians

The American or bronze race originated in the New World, to which they are still confined, possibly having been an offshoot from the Mongolian race They have diminished in numbers very greatly since the fifteenth century They are being "preserved" in certain reserves in the United States and Canada In South America many tribes are still independent The men of this race are impassive and wary, their religion is nature worship or some form of polytheism

The so called **Caucasian** or white race seems to have originated in Northern Africa or Western Asia and to have spread in early times all round the Mediterranean Sea, then it spread over Europe and into Persia and India In quite modern times the race has peopled much of North and South America, South Africa, Australia, and New Zealand

The Peoples of Europe—This continent is inhabited chiefly by "Caucasian" people, the exceptions are the Turks, Bulgars, Hungarians, Lapps, and Finns, who are Mongolian people Modern study recognises three divisions which do not correspond with languages The first, and probably the oldest, "race" is the Mediterranean This race came from North Africa, probably in Neolithic times, and the ancient Egyptians and the modern Berbers are African branches of the race

Other branches of this race invaded Europe across the three routes where the sea is most easily crossed The Iberians crossed by the Straits of Gibraltar and occupied the peninsula The Ligurians crossed over Sicily and occupied almost the whole of Italy They passed along the coast until they came into conflict with the Iberians in the south of France The Pelasgians,

the third group, came across the eastern Mediterranean and reached Greece and the islands *Mediterranean Man* established himself round the great inland sea, probably displacing earlier races of Palæolithic or early Neolithic types He became thoroughly adapted to the environment of hot, dry summers, and his adaptation has enabled him not only to retain nearly all his early conquests, but also to extend north-westward along the Atlantic seaboard until he had peopled France and most of the British Isles This race includes the Romance-speaking and Celtic-speaking peoples of South-Eastern and Western Europe

Possibly from Mediterranean man, and perhaps in later Neolithic times, there developed an offshoot adapted to the forest lands of Central and North-Western Europe This is *Nordic Man*, a race tall in stature, with fair hair, blue eyes, and light complexion, in contrast with the lower stature, dark hair, and dark eyes of Mediterranean man It has been suggested that Nordic man originated as such in Scandinavia, that is, Scandinavia in the wider sense, including Denmark This race was as perfectly adapted to the moister conditions, to the deciduous forests, coniferous forests and marshes as Mediterranean man was to the dry summers and irrigated alluvial plains of his region This northern and north-western race is like the Mediterranean race in having a relatively long skull—a most important similarity, and one which divides him sharply from the next race to be considered

Alpine Man—Mediterranean man belongs, broadly speaking, to the peninsulas and islands of Southern and Western Europe, Nordic man belongs to the lower hills and the plains of Northern Europe and the northern peninsulas and islands In Middle Europe is the great wedge of newer mountains, of which the Alps are the

culmination Into this region came a great intrusion from the East, a race of man from the great Eurasian plains, probably from beyond the Urals and the Caspian The men of this race were broad-skulled, or round-skulled as some writers say, and of intermediate colouring The broad-headed men seem to have pushed themselves right across Europe to the Pyrenees The race penetrated to Britain, if the evidence of bronze implements and of their peculiar barrows (burial mounds) may be trusted Broad-headed skulls are comparatively rare among the modern British population, and it is believed that Alpine man was only present for a time as a ruling caste in Britain, to be ultimately absorbed in the general population

Alpine man, as represented by the broad-skulled elements in the population, now extends from Belgium across southern Germany to Austria and Russia He also inhabits the Alps and the adjacent highlands of the northern Balkans He was essentially a pastoral man, of nomadic habits, which he had acquired by long adjustment to the environment of the steppes Except that he has adapted his pastoral habits to the Alps, and modified his nomadic habits to suit his herdsman's life there, the name Alpine is not a very happy one Eurasian is better, and some writers have used Celto-Slavic The old name Slavonic is obviously included in this more modern race-name

We have thus a picture of Europe inhabited mainly by three varieties of the Caucasian race, Mediterranean, Nordic, and Alpine, with intrusions of Mongolians in Turkey, Bulgaria, Hungary, and Finland If this modern reading is correct, it is obvious that the connection between race and language is only slender and uncertain, and that it cuts across nationality in many directions The British Isles may be taken as illustrat-

ing one of the peculiarities of language and race Early Mediterranean man had his own language, which has become extinct in Britain Alpine man came as a ruling class and imposed his Celtic on the earlier inhabitants Afterwards, across the North Sea, came successive invasions of Nordic man, and again these almost completely imposed their language on the British people Very nearly the converse has happened in one part of Central Europe Bohemia is inhabited by Alpine man, but he largely speaks a Nordic language (modern German) There is a Slavonic movement for preserving the Czech language, and in the capital, Prague, there is a Czech university

A most interesting case of one "race" with different languages is furnished by the Iberian peninsula That region is geographically well fitted to become the home of one race, and with the exception of some Moorish and slight negro strains it is almost pure Mediterranean in type Yet no less than four languages are spoken, all of them probably of Mediterranean origin. Castilian or Spanish, Portuguese, Basque, and Catalan Catalan and Basque overlap somewhat into France at either end of the Pyrenees [1]

It would take too long to study the rest of the Great Caucasian race as fully as the branches in Europe have been discussed. It may be remarked, however, that two great linguistic families are recognised Southern Caucasian and Northern Caucasian The southern family includes the groups called Hamitic and Semitic those inhabiting Mesopotamia, Arabia, Egypt, Northern Africa generally, and the south of Spain The northern family includes the Indo-European or Aryan groups, inhabiting nearly all Europe, Armenia, the Plateau of Iran,

[1] For a study of the Basque problem, see Ripley's *The Races of Europe*

Afghanistan, Northern India, and Ceylon, with the well-known offshoots into America, South Africa, Australasia, etc

It is interesting to note that the three great monotheistic religions arose among the Caucasian peoples Judaism, Christianity, and Mohammedanism Relatively few Caucasians have remained polytheistic, the chief exception being the Brahmins of India

There are naturally many parts of Europe where there has been some fusion of the sub-races, and where there has been long-continued struggle for domination One such region is where the plain of Russia approaches the middle mountains of Europe, there some fusion of the Slavonic division of the Alpine race with Nordic man has taken place, and there the struggle between *Panslavism* and *Pangermanism* is very keen In the region immediately to the west of the Rhine is the persistent difference in outlook between the two races, Mediterranean and Nordic In the British Isles there has been a fusion of the long skulled, dark-haired race with the long-skulled, fair-haired race, that is, Mediterranean with Nordic, and at least some infusion of the broad headed Alpine race At one time it was almost an article of faith to believe that the Nordic overwhelmingly predominated, but opinion has changed considerably of late years, and now the mixed British people are believed by many to be predominantly Mediterranean, with a strong but subsidiary infusion of Nordic, and some leaven of the Alpine This is usually believed to have been of advantage

New racial combinations of great interest and probably of great power seem likely to arise in the future in the "New Countries," such as Canada, the United States, Argentina, Chile, South Africa, Australia, and New Zealand To take North America as an example It

was first colonised largely by Mediterranean man, then afterwards the other European sub-races and the mixed peoples have contributed their share There has been interfusion in varying degree with a remnant of the original American, a strong Ethiopic strain added, and also a considerable infusion of Mongolian blood The results of such a commingling of races and sub-races cannot be foreseen

Nations, Races, and Languages in Europe—Not one of the great nations of Europe is composed of a race in the strict sense, but in most cases one or other of the three great European "races" predominates Spain is, as we have already seen, almost entirely Mediterranean, with some intermingling of a foreign element, the Berber (or Moorish), France is also predominantly Mediterranean, but not to the same extent as Spain, for there has been a considerable infusion of Nordic and a powerful leaven of Alpine Germany is Nordic in the north but largely Alpine in the south, with another strain of Alpine (Slavonic) in the east, Italy is Mediterranean, with some Nordic in Lombardy and Alpine in the north-east Russia is predominantly Alpine, but there are quite foreign elements of various types, Finnish and Kirghiz being the most obvious The former Austria-Hungary was in no sense a nation as determined either by predominance of one race, or as limited by geographical boundaries It was simply a creation of the diplomatists, and proved to be essentially unstable Germans inhabit the valley of the Danube in and near the Austrian Gate Vienna is the centre of the Germanic lobe As already mentioned, Bohemia is inhabited by Czechs—a Slavonic people—who speak both German and a Slavonic tongue The racial question is very acute in that part of Central Europe The great Hungarian plain is inhabited mainly

by Magyars or Hungarians, a people of Uralo-Altaic (*i e* Mongolian) race North and north-east of these are Slovaks and Little Russians, both Slavonic peoples, speaking different languages from the Hungarians and Austro-Germans East from Hungary there is Transylvania, inhabited mainly by Rumanians, speaking a Romance language In this part of Europe alone there are said to be five "nations," five languages, five creeds—an interesting epitome of the inherent difficulties of the former Austro Hungarian Monarchy The south-western regions, Bosnia and Herzegovina, are peopled by Southern Slavs, as also are Croatia and Slavonia more to the north Italians are predominant in the Trentino, in the coast lands of Istria, and in southern Carniola In addition to these dominant divisions it must be remembered that strong German colonies are scattered through many of the larger population areas, especially in Hungary and in Transylvania

Four religions are strongly represented—the Greek Church, the Roman Church, the Protestant, and Jewish The Czechs of Bohemia are Romanists, that religion having been forced on them in the early seventeenth century, in the Thirty Years' War from 1618 to 1648 The Poles of Cracow and western Galicia are also Romanists The Little Russians are devoted adherents of the Greek Church, as are also the eastern groups of the southern Slavs The western Slavs of the Southern group—Croats and Slovenes, nearer to the Adriatic, are Romanists The Rumanians are chiefly of the Greek Church, and the Magyars are chiefly Protestants German-Austria is essentially Romanist in religion

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CHAPTER XXI

THE DISTRIBUTION OF POPULATION AND THE LOCATION OF TOWNS

THE first need of man is food, and the amount and accessibility of food-supply is the first factor in determining his distribution As his wants increase with advancing civilisation, other factors connected with clothing, recreation, and pleasure become important The luxuries of life as well as the pure necessities nowadays play an increasingly important part Food can be transported with such relative ease compared with former times, that man need not dwell so near the region where his food is produced as formerly Even yet there are, however, some of the densest aggregates of population where staple foods are produced in large quantities The relations between man and the food-supply are reciprocal, a dense population grows up on certain favourable fertile lands, and the people produce on these lands every available particle of food, according to their knowledge This reciprocity is well illustrated in the densely peopled lands of China and India, to which further reference will be made later

Highly civilised communities have usually passed through three stages in relation to their food-supply and other wants In the earlier times they are pastoral and more or less nomadic, moving from one region to another as the food-supply for their flocks fail After this they have become agricultural and settled, and the

cultivation of grain, roots, and fruits adds to their simpler resources Finally, they have become commercial and industrial, producing commodities other than foods in exchange for imported supplies of the latter.

The typical nomads are found, of course, in deserts and on steppes and prairies The inhabitants of the Kirghiz steppes of South-Western Asia live almost exclusively on the products of their flocks and herds, seldom using even bread Their food is flesh and cheese, and their drink fermented milk

The agricultural stage is illustrated by many young nations, such as Canada, Argentina, Australia, and by the peoples inhabiting the rich alluvial plains, such as the Yangtse, the Ganges, the Nile England has fully reached the industrial stage, and the British Isles, as a whole, produce only a comparatively small proportion of the food required by their people England was an agricultural country until the industrial revolution of the eighteenth and nineteenth centuries, and between say 1700 and 1900 has passed quite from one stage to the other Germany was predominantly agricultural until quite recently, but of late years much food has had to be imported Even a young country like the United States is apparently passing from the agricultural to the industrial stage It would, however, be better to regard the United States not as a *country* in this respect It is rather to be regarded as a federated continent, some portions of which are pastoral, some agricultural, and some industrial

In the nature of things population can never be very dense in the pastoral or nomadic stage of development, and all such regions are but sparsely peopled Some agricultural regions and most industrial regions are densely peopled The distribution of population ultimately depends upon climate, fertility of soil, mineral

wealth, and means of intercommunication, using the latter term in its widest sense The four factors mentioned are of very different values in different regions and are usually closely interrelated

Thinly Peopled Lands—It may be well to indicate, at the outset, some of those regions where population is very sparse, these are some parts of the hot, wet, equatorial forest, tropical deserts, deserts in the temperate zones, the tundra, the Arctic Highlands, and some high mountain regions and very high plateaux in various parts of the world

In the hot, wet forests the undergrowth is so dense that communication is very difficult except on the rivers The soil consists largely of decomposing vegetation, the air is laden with disease germs, and germ-bearing insects abound, little sunlight penetrates the overhead canopy of vegetation, the glades are gloomy and depressing, and poisonous insects, venomous snakes, and beasts of prey make human life insecure The dense equatorial forest is, therefore, the home of a few degenerate American Indians, or Negroes, or Malays

The deserts are permanently inhabited only on the oases, the latter being determined by a spring or a deep well The Nile Valley is a long narrow oasis in an almost rainless region, it is, of course, the river that is entirely responsible for the habitability of lower and middle Egypt In a somewhat lesser degree this is also true of the Mesopotamian valley, and of the lower Indus Outside the oases there are only a few nomads who move from one fertile spot to another The great Sahara is the conspicuous example, there an area of three million square miles (that is, three-fourths the size of Europe) contains probably at most little more than one million people Arabia, the highland deserts of mid-Asia, and the Australian dry regions are also very thinly peopled

Beyond the Arctic Circle human habitation is difficult and the number of inhabitants very small The continued absence of sunlight during the long winter lowers the vitality of man, food is very scarce, most of it coming from the sea, and there is little to attract the average man The population is confined to a few Eskimos and similar tribes, who eke out a very precarious subsistence The Lapps of the far North of Europe, who have the advantage of the gulf of winter warmth caused by the Atlantic drifts and the warm south-westerly winds, are the most advanced of Arctic peoples Some of them are settled on the northern fiord coast and maintain themselves by fishing, the others are nomads who inhabit the interior, and with their dogs and reindeer wander from place to place in search of pasture for the latter animals

Assuming that the known lands in the Antarctic regions are parts of one great Antarctic Continent, there may be a land mass in the far south with an area almost or quite equal to that of Australia So far as is yet known, there are no land mammals whatever, and of course no human inhabitants There are numerous species of birds, and seals and whales are plentiful in places There does not seem to be any land flora This, therefore, is almost the largest absolute desert on the earth's surface

Greenland may serve as the type of Arctic highlands The land is fringed with fiords like many of the northern lands, and Eskimos inhabit the coast up to about 78°–80° N It is estimated that there are about 10,000 Eskimos in the whole of Greenland, together with the few Danes who administer the country and carry on its foreign trade The great inland plateau of ice, which stretches nearly from coast to coast, is uninhabited

Lastly, among the sparsely inhabited regions may be

mentioned the high mountains and plateaux where either Arctic highland or tundra conditions are reproduced Above the snow-line permanent inhabitants must obviously be very rare A little below the snow-line are only a few herdsmen, except in regions such as Switzerland and Norway, where nearness to the dense population of industrial Europe has made of the mountains a playground, and where hotel-keepers, guides, and a few others depend upon the increasing number of tourists who visit the mountains in search of knowledge, pleasure, or adventure The higher parts of the great Tibetan plateaux, alike with the neighbouring Alpine mountains, such as the Pamirs and Karakorum, form another great region with a sparse population The intense cold of the winter, the icy blasts, and the low atmospheric pressure, combine to render such lands almost uninhabitable.

Densely Peopled Lands —We may now turn to the other extreme, where large populations are concentrated on a small area There are clearly two main types First, those lands where food is plentiful and cheap, and where a rich soil and a favourable climate produce enough to satisfy the needs of a large, if not very exacting, population The plains of China at once occur as illustrations The rich alluvial soils of the Si-Kiang, the Yangtse, and the Hoangho valleys, and of the coast lands support an enormous population The summers are regularly hot and moist, controlled by the monsoons which blow from the warm seas Agriculture is regular and the climatic conditions reliable, and almost every inch of the rich soil of the great alluvial plains is utilised The winters are dry and comparatively cold, and a period of rest for the worker and for the land is insured Under these conditions there has come to be the densest population of agri-

culturists and almost vegetarians that the world knows The plain of the Ganges and the Punjab part of the Indus are similar The alternation of warm, wet summers and dry "winters," coupled with the wonderful fertility of the immense stretches of rich alluvial deposits, cause the enormous agricultural wealth of India, and are largely responsible for the vast population of the plains In Bengal and the United Provinces (Agra and Oude), with an area of 183,000 sq miles (that is, 29,000 sq miles less than France), there is a population of 92,000,000 (cf France again with 41,000,000) [1] Most of this enormous population is dependent upon India's chief industry, which is now, as it always has been, agriculture

A remarkable example of a densely-populated agricultural land is that of the lower Nile trough, set in the great desert If the desert areas of Egypt are included the population of the country works out at about 37 to the square mile If the desert be excluded the density is over 1000 to the square mile, which is very high The rich silt of the overflowing Nile, deposited over the land from before the dawn of history, has made the support of a dense population possible As the marshes of the delta are drained and reclaimed this population tends to increase At present an area of 13,000 square miles supports a population of over 14,000,000. Yet another example of a densely peopled agricultural region is the plain of Lombardy The rivers of the Alps and the Apennines have spread over the sunken block an immense thickness of mixed debris, which has come from the varied geological formations of the mountains Wheat, maize, and rice are grown in large quantities and support a large population This

[1] Of course there are many relatively infertile parts of France included

region is not so purely agricultural as the others mentioned, for manufactures are carried on chiefly in the towns , silk, woollen, and linen spinning and weaving give employment to a considerable number of people

All these examples of dense population are of long standing, but there are other thickly peopled regions which are quite modern in origin, and are characteristic of modern civilisation These are the industrial regions usually located on or near the coal-fields The great industrial region of east and south-east Lancashire may be taken as a type Here the soil is infertile and the climate far from attractive The rainfall is not heavy, but it is distributed throughout the year, three days out of five having some rain There is much cloud and consequently not much sunshine Yet there is aggregated a very closely packed population, chiefly engaged directly and indirectly in coal-mining and cotton manufacture, and the allied engineering and chemical industries Here is a population of from five to six millions, and the commercial capital, Manchester, has become a focus for almost ten millions of people It is somewhat outside the scope of the present work to discuss fully the reason for the localisation of industries, but it may be stated briefly that in Lancashire some of the determining factors have been coal, nearness of salt (for chemicals), a humid atmosphere, and plenty of small rivers with soft water from the grit hills

Other industrial regions with dense populations are the Midland Valley of Scotland, the North-Eastern region of England (Blyth to Middlesbrough), the West Riding with an extension into Derbyshire and even to Nottingham, the great Midland region with Birmingham as a centre, and the South Wales coal-field

To these, which are largely determined by the presence or nearness of coal, and which are essentially products

of the Industrial Revolution, may be added Greater London with its 8,200,000 of people, its great and varied industries, its immense shipping trade, and its vast financial interests. London's convenient river mouth, its excellent position facing the continent, its choice in early times as the capital of a progressive country, and perhaps above all the daring foresight and industry of its merchants, have made it the world's greatest port and commercial and financial clearing-house The county of London, with Croydon, Rickmansworth, Watford, St Albans, and many other towns and villages, are all part of greater commercial London, and the extension of electric trains and motor buses is drawing a still wider area into the always extending London

On the Continent of Europe the chief industrial regions with dense populations are Belgium, especially south Belgium, in the Sambre-Meuse Valley, where a coal-field extends almost continuously across the country from north-east France to Aix-la-Chapelle From Lille and Roubaix, through Tournai, Mons, Charleroi, Namur, Huy, and Liège to Verviers and Aix is one busy manufacturing region, with intervals in the dolomitic limestone region of the Meuse, between Namur and Huy, where the population is not so dense as in the other parts In addition to the coal on the spot there are iron ores not far away, and there were zinc ores in the vicinity The rivers Meuse and Sambre, and the magnificent system of railways and canals, complete the facilities for transportation The Westphalian region, in the valleys of the Ruhr and the Lippe, is another busy industrial province, where great iron, textile, and chemical industries are located The coal of the district is used to smelt the iron brought down the Rhine from Lorraine and Luxemburg, and much ore now comes from abroad.

In the immediate district there is a population of about 3,500,000, and a dozen towns of over 100,000 each, thus making a district almost comparable with East Lancashire The chief towns of that busy region are Dusseldorf, Essen, Duisburg-Ruhrort, Dortmund, Elberfeld, Barmen, Bochum, Krefeld, and Mulheim In a part of Saxony is one of the densest populations of Europe, where 5,000,000 people are condensed on about 15,000 square miles There are found coal and lignite, and much metal-mining is carried on even yet, though the mines have been worked for centuries There has also grown up a great textile industry, in some measure a rival of that of Lancashire and the West Riding of Yorkshire Add to these the manufacture of locomotives, machinery, and chemicals, and it will be understood how a great industrial region is located there, the chief towns of which are Leipzig, Dresden, Chemnitz, Meissen, and Zwickau

The last of the great industrial regions which we shall discuss is that of the coal-field of Pennsylvania and Ohio Pittsburg may be taken as the centre of the immediate busy manufacturing region It has immense iron and steel works The original ore of the district has been nearly worked out, but ore is now brought in enormous quantities from the Lake Superior region There is abundance of coal, and there are also the large stores of petroleum To these advantages of raw materials in great bulk must be added the facilities for transportation The Great Lakes, the Erie Canal connecting to the Mohawk Valley and to the Hudson, and the excellent railway systems give ready facilities for communication with the Atlantic seaboard, with Canada, and with the rich agricultural lands of the interior It will be readily understood how this has come to be North America's busiest district and the

region of its densest population The greater region now under consideration includes the following cities Pittsburg (669,000), Buffalo (573,000), Cleveland (900,000), Detroit (1,500,000), Cincinnati (451,000), Columbus (290,000), Toledo (290,000), and Dayton (200,000).

All these great industrial regions are situated on coal-fields or not far from coal supplies, and where the means of communication and transport are excellent In the present stage of industrial development coal is the strongest factor, but it does not follow that this advantage will be maintained Already there is taking place a great development of electrical power derived from water-supply Norway and Sweden, the hilly regions of Saxony, Switzerland, Eastern Canada, and the United States have so far led the way Power is now transmitted for great distances in both Switzerland and the United States, and this may lead to new distributions of manufactures and of population in the future

The Location of Towns—When man passes out of the purely nomadic pastoral stage he needs permanent settlements Towns therefore grow up where he can exchange his commodities, and in the earlier agricultural stage where he can receive protection for himself and his property. Towns were usually begun in places which could be easily defended, either by means of a commanding fort or by placing the town where it would be safe from attacks Athens, Edinburgh, Carcassonne, Lincoln, Stirling are famous towns which were under the protection of hill forts Many towns were built on islands, examples of which are Paris on an island in the Seine, Ely on an "island" in the Fenland, Venice on an island among lagoons, and Bombay on an island in the sea Many towns have grown upon land in bends of rivers, where they would be relatively

difficult to attack Durham, Toledo, Besançon, are examples

Another type of town is where routes meet, and of these there are numerous examples A simple case is where break of bulk occurred owing to a great mediæval roadway crossing a river, and in the case of such towns as Oxford, Hereford, Utrecht, the name refers to the crossing The old Watling Street of England passed through Fenny Stratford and Stony Stratford Other well-known English examples are Stratford-on-Avon and Watford Strasbourg stands where the old Crusaders route passed round the northern end of the Vosges towards the crossing of the Rhine Orleans stands where the route from Paris to the south crossed the Loire, and numerous other examples might be given

Confluence towns are perhaps more numerous than any other type, they are found in all types of civilisation, eastern and western, ancient and modern The simplest case is where two navigable rivers meet, or two rivers which determine roadways through a country Reading, Lyons, Namur, Allahabad, Khartum, Hankau, Montreal, St Louis,[1] may be investigated by the student The simple crossing of well-used routes provides another group of towns Vienna on the crossing of the east to west and north to south routes is a good example Liege is another case where two important mediæval routes crossed, and in modern times important railways cross at the same place

Important towns often stand where intermont valleys open out into a plain Consider those eastern Pennine rivers which make up the Yorkshire Ouse At the "mouth" of the Swale is Richmond, on the Ure is Ripon, on the Nidd, Knaresborough, on the Wharfe, Tadcaster, on the Aire, Leeds, on the Calder, Wakefield,

[1] Near the confluence

and on the Don, Doncaster It is interesting to note the difference in development between Leeds and Wakefield on the coal-field and the northern group, which are still comparatively quiet market towns Doncaster has become a great coal centre, though it is not on a coal-field on the geological map A "buried coal-field" is responsible for its remarkable growth in recent years

Perth, Stirling, and Dumbarton are similar gateway towns to the routes into the highlands Cologne, Liège, and Namur are of this character, as also are Turin, Milan, and Verona

A large number of famous towns occur at the tidal limits of estuaries, that is, at the farthest point to which early shipping could penetrate, which was often also the lowest point where the river could be easily bridged or forded London is a classic example Bristol, Newcastle, Hamburg, Bremen, Nantes, Bordeaux, may be mentioned among others As modern shipping has grown bigger and bigger, the trade has either left many an old tidal port, or an outport has enabled the older town to maintain its ground Glasgow, Newcastle, London Bristol, Hamburg, Bremen, Nantes, Bordeaux, have all important outports

Havre has developed as a great port of France because it is on the open sea Southampton and Liverpool need no outports In non-tidal seas, towns very often stand on bays or natural harbours, examples being Marseilles and Naples

The towns at the ends of the drowned valleys on the eastern seaboard of the United States have already been mentioned Washington, Baltimore, Philadelphia, and Trenton stand just at the head of easy tidal navigation, where the rivers open out into a wide estuary

Geography can thus explain from obvious natural

causes the position of many types of towns There are others which are due to what may be called more artificial causes Towns where mineral wealth is the first consideration, such as Johannesburg, Wigan, and Coolgardie, may be taken as examples Rome and Mecca owe much to religious sentiment, without which (especially in the case of the latter) they could scarcely have retained their importance in modern times Petrograd and Berlin owe much to determined princes who resolved to make them into capitals of kingdoms or empires Washington and Ottawa have been selected as capitals of federation of states, and in both cases the work of administration maintains a considerable population

Modern industrial towns are not always easy to explain In some cases they are very old towns rejuvenated, Leicester, Derby, Nottingham, Liege are cases in point Manchester, Leeds, and Birmingham trace their origin back to very early times, but their modern importance is shown by such facts as the late period when they were first represented in Parliament Not one of them was reckoned as of first-class importance in the Civil Wars of the seventeenth century The Ruhr-Lippe group is of similar modern growth The great industrial towns of the United States are of necessity modern Their enormous growth is due to the tremendous natural resources of a rapidly-developing continent

With the great development of railways, and the very great dependence of modern industrial life upon them, new nodal towns have in many cases grown up where a system of lines radiate, or the railways have been attracted to old towns, following more or less the routes of the mediæval roads Of the new centres, Crewe is a good example Many of the old and im-

portant towns have also developed into modern nuclei of railway traffic, Rugby, York, Carlisle, in Britain, Namur, Prague, Warsaw, and many others on the Continent, may be quoted All great capitals are now the meeting-places of numerous railway lines, and thus towns which were important before, have gained a new source of wealth

Finally, many new towns in new countries owe much of their importance to the railways, converging on them Montreal, Chicago, St Louis, Winnipeg may be mentioned as American examples

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SECTION E

CHAPTER XXII

MATHEMATICAL GEOGRAPHY AND CARTOGRAPHY

The Earth, its Shape and Size.—The spherical form of the earth was well known to the Greek geographers, and Eratosthenes and others had made attempts to estimate its circumference by measuring an arc of its curved surface. This knowledge became a part of the teaching of the age, but in the long period which followed the break-up of the Roman Empire it was known only to a few scholars here and there, and most of the people who thought about it at all had other ideas. With the great revival of learning which characterised the passing of the Middle Ages, men rediscovered the almost forgotten knowledge of the Greeks. Copernicus and his followers began to teach that the earth was round and that it was but one member of the Solar System.

It was some two hundred years later before it became quite clear that the earth is not a true sphere, but that it is what is called an *oblate spheroid*[1]—that is, having the shape which would be assumed by a rapidly rotating body cooling from the liquid condition. The teaching of Newton paved the way for this knowledge, and with the more accurate determinations of the length of an arc of latitude which were made in the latter part of the eighteenth century, aided by numerous pendulum

[1] See Glossary.

observations in both high and low latitudes, the earth's form became fully known

If the earth were a true sphere it is obvious that every correctly measured arc of latitude of one degree along a meridian would have the same length, that this is not so appears abundantly from the following table

Latitude N or S	Length of 1° of latitude, measured from ½° above to ½° below the latitude shown in 1st column
0°	68 69 miles
10°	68 70 ,,
20°	68 77 ,,
30°	68 88 ,,
40°	69 00 ,,
50°	69 10 ,,
60°	69 21 ,,
70°	69 32 ,,
80°	69 38 ,,
90°	69 39 ,,

It follows from this that the equatorial diameter of the earth will be greater than the polar diameter The figures are approximately

Equatorial diameter, $e=7926\ 6$ miles

Polar diameter, $p=7899\ 6$,,

The flattening or oblateness $=\frac{e-p}{e}=\frac{1}{294}$ approximately

It is not necessary in this book to insist upon the elementary proofs of the earth's curvature and of its approximately spherical shape, but the reader may be reminded that the curvature is not noticeable in such a short distance as a mile If, however, two points 10 miles apart are selected on perfectly "level" ground they cannot be seen from each other because of the

earth's curvature. A man of average height can see a point on flat ground about 3 miles away but no farther; if he stand on a raised support he can see increasing distances, his vista being limited by the small circle of the earth that forms his horizon.

A striking way of illustrating the curvature of the earth's surface is to quote the fact that if the chord of the arc could be drawn from St Alban's Head to Berwick, the curved meridian line of 2° W would be 4 miles above this straight line in middle England.

The Earth's Rotation and Revolution.—The shortest diameter of the earth—the polar diameter—is the axis of the earth's rotation; this rotation causes the familiar phenomenon of day and night. The earth is at the same time travelling through space in an elliptical orbit round the sun as focus; this motion is known as the revolution of the earth round the sun. Conceive a line drawn from the centre of the earth to the centre of the sun; call this the earth-sun line. As the earth's path of revolution is an ellipse with the sun at one focus this line varies in length, its average length being approximately 93,000,000 miles. It is easy to think of this imaginary line as tracing out an ellipse during a complete revolution of the earth round the sun; the plane in which this ellipse lies is called the Plane of the Ecliptic. The earth's axis is not at right angles to this plane, but is inclined at an angle of 66½° approximately, or, stated in another way, the plane of the earth's equator is inclined at an angle of 23½° to the plane of the ecliptic.

The earth's axis maintains its inclination of 66½° during the whole of a revolution, hence there results the different incidence of the sun's rays upon the earth which makes the phenomenon of the seasons. Four critical positions may be defined and readily understood; these are at the solstices (June 21–23, December

21–23) and the equinoxes (March 21–23, September 21–23) The reader who finds any difficulty in realising these different relationships may easily demonstrate them by putting a knitting-needle through the "axis" of an orange and then carrying the orange round a small lamp, taking care to maintain the axis tilted at the same

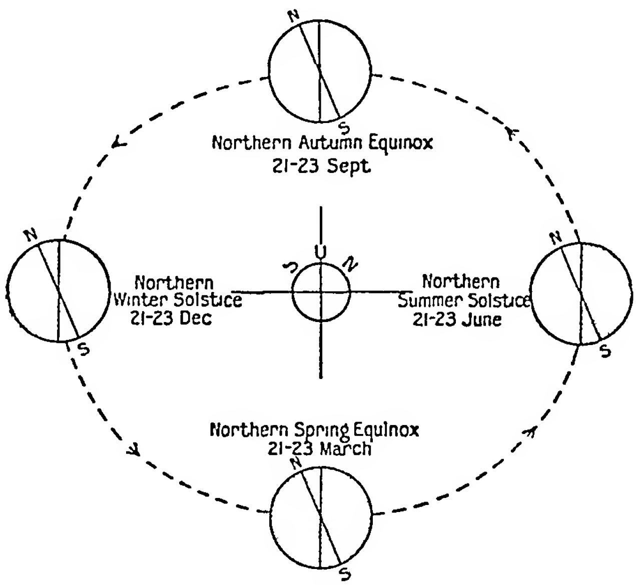

FIG 77 —DIAGRAM OF THE EARTH'S ANNUAL REVOLUTION, AND THE CAUSE OF THE SEASONS

angle and pointed in the same direction throughout the whole revolution The four positions mentioned above may be represented diagrammatically as in Fig 77 Repeat the illustrative experiment and study the figure until the significance of the small circles—the Arctic Circle, the Tropic of Cancer, the Tropic of Capricorn, the Antarctic Circle—is perfectly clear Refer again to Fig 77

Great and Small Circles on the Globe—The equator is the boundary or circumference of that section of the sphere which bisects the earth's axis at right angles, or the equatorial plane is midway between the poles and at right angles to the axis This circumference is very nearly a true circle, whose length is $\pi \times 7926.6$ statute miles, or approximately 24,902 miles All the possible circles which may be drawn on the earth's surface *parallel* to the equator, and whose planes cut the axis at right angles, belong to the class of small circles—that is, circles which do not contain an equatorial diameter, the two tropic lines and the Arctic and Antarctic circles are examples An infinite number of such small circles can obviously be drawn, the four mentioned are important ones which are determined by the definite relations of the earth to the plane of the ecliptic Parallels of latitude (which are discussed later) are small circles The small circles which are not parallel to the equator are not of much importance to the geographer

The equator obviously contains an infinite number of equatorial diameters, any other circle drawn round the globe which contains an equatorial diameter is defined as a great circle It is apparent that every great circle, other than the equator, is bisected by the equator Among the infinite number of great circles which can be drawn on the globe a most important group to the geographer consists of those which pass through both poles, cutting the equator at right angles These great circles are called meridians Other great circles which do not pass through the poles are of interest to the navigator, but are not very important to the geographer, an exception is the one which cuts the equator at an angle of $23\frac{1}{2}°$—the great circle above which the sun appears to trace out its path in the heavens

The two sets of circles—the great circles drawn through the poles and the small circles drawn parallel to the equator, are the important circles most frequently used by the geographer, they are the meridians of longitude and the parallels of latitude

Position on the Earth's Surface —It is often inconvenient to use linear measurement for indicating the position of places on the earth's surface On the ocean, in desert lands, in tropical forests, and across high mountain ranges, it is exceedingly difficult to make linear measurements of distance at all over any considerable extent, the method of co-ordinates must be used and the determination of position is made by reference to some body in the heavens In the usual methods of co-ordinates there are two lines of reference, and in the simpler cases these are at right angles to each other One such line at once suggests itself for the earth's surface, namely, the equator, this is the reference line for *latitude*, which is defined as angular distance north or south of the equator For longitude there is no such obvious line, and one has to be selected arbitrarily The meridian which passes through the Observatory at Greenwich is always employed by British astronomers and geographers, and most of the other nations now use this meridian *Longitude* may therefore be defined as angular distance east or west of the meridian of Greenwich The position of a place is fully stated when its latitude and longitude and its elevation above sea-level are given

Determination of Latitude —This can be done approximately by finding the altitude or angular elevation of the Pole Star This star is slightly more than a degree from the celestial pole, and allowance can be made for the difference The method more usually adopted is to find the altitude of a star when it crosses the meridian

Or instead of one reading, several readings of the altitude are taken, so as to be quite sure of obtaining the one of greatest angular elevation Call this angle α The angular distance from the zenith will clearly be $90°-\alpha$ Another factor needed is the declination of the particular star—that is, the angular elevation of the star above the celestial equator at the time of the observation This is obtained from the *Nautical Almanac*, which is published annually by the Admiralty Call this declination δ The latitude is obtained from the formula $L=90°-\alpha+\delta$ For very accurate work refinements of observation are introduced so as to determine α within the least possible margin of error

Determination of Longitude —As the earth rotates on its axis the meridians come successively "under the sun" or under a given star, and the true time of a place is clearly dependent upon its longitude A complete rotation takes place in 24 hours, hence 24 hours of time correspond to 360° of longitude, or 1 hour is equivalent to 15° of longitude, and 1° of longitude to 4 minutes of time The longitude of a place is thus the angular distance corresponding to the difference between the true time at the place and Greenwich time Supposing we know Greenwich time and can also determine the instant when the sun is on the meridian at that place, then it is a simple calculation to find the longitude The problem resolves itself into two factors—the first is finding the meridian time, the second is knowing Greenwich time accurately

To find the meridian time at a place, the time of transit of the sun across the meridian is taken and corrected by what is called the equation of time, which is obtained from the *Nautical Almanac* This gives the mean Noon time of the place, and from this the longitude is at once obtained

A second method is that of equal altitudes A theodolite is set up, and the time at which the sun crosses the horizontal wire of the instrument is noted The theodolite is then swung through 180° in a horizontal plane, keeping the inclination of the telescope fixed The time when the sun crosses the horizontal wire a second time is noted The time of transit across the meridian is midway between these two times This gives local noon, and if Greenwich time is known accurately a comparison of the two gives the longitude

A third method commonly used is to determine the angle between the meridian of a heavenly body and the meridian of the place, this angle is called the Hour Angle of the heavenly body, from it, by solution of a spherical triangle, the time of transit of the heavenly body may be obtained, this in its turn gives local mean Noon, and from a comparison of this and Greenwich time the longitude is obtained

In all these methods a knowledge of Greenwich time is assumed This was formerly obtained by carrying special timekeepers, called chronometers, which are very accurately made These are kept with very great care, and time can be read to a second Within recent years Greenwich time has been sent out by telegraph, and by determination of local time the longitude of many places has been more accurately determined Greenwich time is now sent out by wireless telegraphy, and as navigators and travellers on land can readily carry portable sets for this work, the determination of longitude has been rendered easier, always supposing that local time can be accurately determined

Longitude and Time Local Time —Noon at any place is the time when the sun passes the meridian of that place, and it is obviously the same for all places on the same meridian Places west of Greenwich have

their noon later than Greenwich, and places east of Greenwich have theirs earlier than Greenwich Philadelphia is nearly in longitude 75° W , its noon will occur when the time is 5 p m at Greenwich , St Louis and New Orleans are almost on the meridian 90° W , their local time is 6 hours behind Greenwich time Calcutta is not far from the meridian 90° E , its local time is taken as 6 hours ahead of Greenwich time Comparing Calcutta and New Orleans, the difference in time is 12 hours, the time at the latter town being 12 hours behind that of the former

Here is an interesting case involving an important result , a vessel sailing *eastward* from the meridian of Greenwich has to put forward its clock 4 minutes for every degree of longitude traversed, so as to conform with local time , when longitude 180° E is reached the clock will have been put forward 12 hours and, completing the circuit of the globe and still travelling eastward, another 12 hours, making an addition of 24 hours for the circuit , to compensate for this addition of 24 hours to the time it is necessary to add a day to the calendar by giving the same date to two consecutive days Similarly, in travelling *westward* there is an alteration in time of 24 hours, but in an opposite sense, 4 minutes being deducted for every degree of longitude and 24 hours being lost in the complete circuit , it therefore becomes necessary to drop one day from the calendar By international agreement this is done at the meridian 180° E or 180° W (these being coincident), and this meridian forms the basis of the " International Date Line " , theoretically the line should be the meridian, but as this passes through a few islands an agreed detour has been arranged and the actual " Date Line " follows a slightly zigzag course, keeping as near as possible to the meridian of 180° E or W

Maps, and their Use

Maps are in such constant use by the geographer that a brief statement concerning them may not be out of place in this book They are of many different kinds and have different aims, for a full description of which some of the books mentioned in the Bibliography to this chapter may be consulted

World Maps—A map of the world or of a hemisphere can represent only very generally and broadly the shape, or the area, and some of the main features of the earth's surface Such maps are drawn on a very small scale, for example, a Zenithal Map on a scale of 1 40,000,000 is in common use

Atlas Maps of continents and countries, or maps of great river basins and of such seas as the Mediterranean, can show more detail, they are, however, much generalised, and the scale is still a very small one For example, a map of the British Isles on the scale of 1 6,500,000 is in general use in popular atlases

Topographical Maps—These are maps of smaller regions, showing with much greater detail and with some approach to accuracy the features they are intended to represent. The "half-inch," "one-inch," and "six-inch" maps of the English Ordnance Survey may be taken as examples, and almost every country has now its maps drawn on similar scales The scale of the half-inch to the mile map is 1 126,720, that of the 1 inch to the mile is 1 63,360, and that of the 6 inches to the mile is 1 10,560 For some purposes a map on a scale of 25 inches to the mile is made, the scale of this map is 1 2,534 4 The numbers given above are technically known as the Representative Fractions for the maps in question An International Map was in course of construction, by agreement between many

nations, when the Great War broke out and delayed its progress for the time being, the scale of this map is 1 1,000,000, or, stated in English measure, 1 inch is equivalent to 15 78 miles approximately

Map Projections —The lines of latitude and longitude form the basis of the map, and the various methods of making the network of these lines, or graticule, will now be studied briefly It is obvious that these lines cannot be drawn accurately on a plane surface This may be illustrated in various ways It is possible to fit a piece of gummed paper about the size of a postage stamp quite closely to the surface of an ordinary school globe, but if an attempt is made with a piece of paper 2 inches square (4 sq inches in area), it will be found impossible to fix it closely to the curved surface without creasing the paper

A good illustration may be obtained from one of the children's cheap balls coloured in octants Cut out from one of these hollow balls one of the equilateral spherical triangles as accurately as possible That the octant is an equilateral triangle is clear, because each side is a quarter of a circle, but the triangle is different from any possible plane triangle as each angle is a right angle, and the three angles of the triangle are equal to three right angles Such a triangle cannot be made into a plane triangle without distortion, and if it is to be tacked down to fit closely to a plane surface it must be pulled out of shape

When the network of lines of latitude and longitude is transferred to a plane surface for the purpose of map-making, the lines may be so adjusted or re-drawn that one of three main conditions may be fulfilled

The map may preserve directions correctly, and the shapes of local features will be correctly represented,

but the relative areas are wrong, such a map is called orthomorphic, isogonal, or conformal.

The graticule may be drawn so that the areas on the map are proportional to areas on the globe throughout, but the shapes are quite wrong, especially near the margins Such a map is called equivalent, or equal-area, or homolographic

It is not possible to construct a graticule so that the map shall be both orthomorphic and equal-area, but the lines of latitude and longitude may be so drawn that, while the map is neither orthomorphic nor equal-area, it is not very seriously wrong in either sense

The chief methods of drawing the graticule of parallels and meridians may be classed under four heads for convenience of study

1 Projection on a plane which is tangent to the sphere, or on a section plane of the sphere
2 Projection on a cylinder which is tangent to the sphere—that is, on a tangent cylinder, or more rarely on a cylinder which is imagined to cut the sphere
3 Projection on a cone which envelopes the sphere and which is tangent to it, or on a cone which may be imagined to cut the sphere
4 The graticule is drawn according to an arbitrary or conventional plan, so as to secure some special phase of accuracy or ease of construction, and the method cannot be called a projection in the strict geometrical sense The networks drawn according to the plans of groups 1, 2, 3 are frequently so far modified by adjusting or re-drawing some or all of the lines that the method is no longer a true, simple projection, and the graticule passes more or less completely into the fourth group Examples will appear in the sequel

Class 1 Projections on a Plane. — There are sub-groups of this general class In the first group the plane of projection is a tangent plane, and the point of origin or focus of projection is the centre of the sphere This is called the *Gnomonic* or *Central Projection* A common position of the plane of projection is the tangent plane

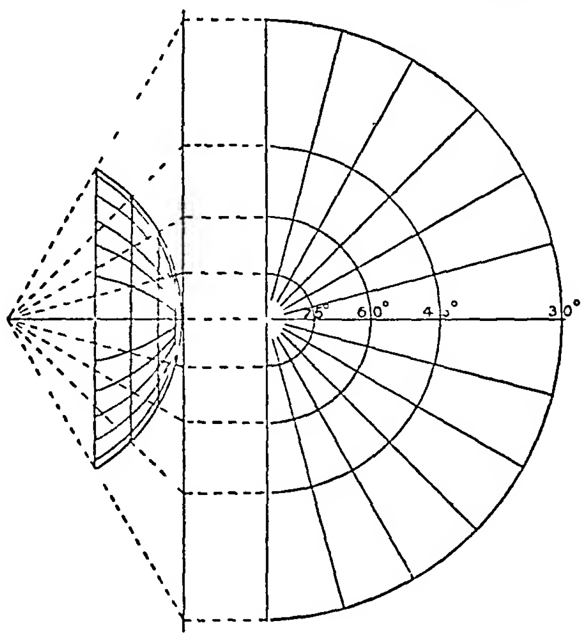

FIG 78 —POLAR GNOMONIC PROJECTION

at the pole, and it is then called the Polar Gnomonic Projection From Fig 78 it will be readily seen that the graticule can only be constructed to show less than a hemisphere The projection is neither orthomorphic nor equal-area, and the exaggeration beyond 30° from the centre of the map is too great for it to be widely used The azimuths or angular directions of points from the

centre of the map are correct, and this polar gnomonic projection gives a moderately good network for not more than 30° round the pole

The plane of projection may be other than the plane tangent at the pole, but the latter is commoner than the other cases

In another sub-group the point of origin or focus is on the opposite side of the sphere from the tangent plane, and at the other end of the diameter which is

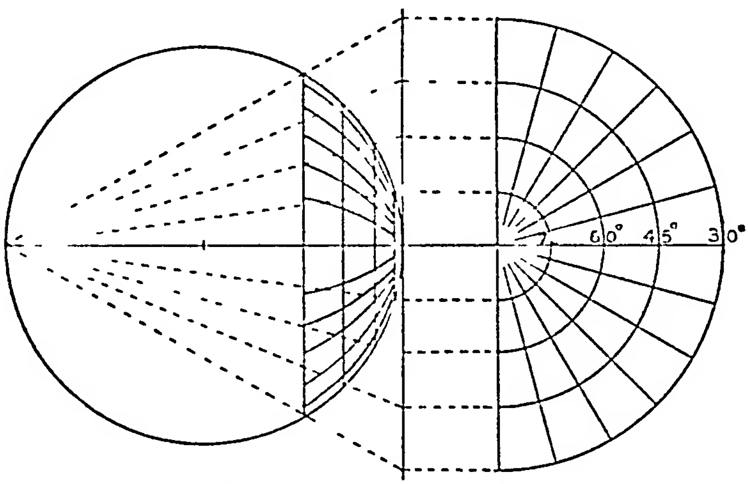

FIG 79 —POLAR STEREOGRAPHIC PROJECTION

at right angles to the projection plane This is the *Stereographic* projection It is an orthomorphic projection, the meridians and parallels intersect at right angles, and small areas have the same shape on the map that they have on the earth's surface As in the case of the gnomonic there are three aspects possible, depending on the position of the tangent plane of projection, they are known as polar, meridian, and horizontal—terms which will be best understood by reference to Figs 79 and 80

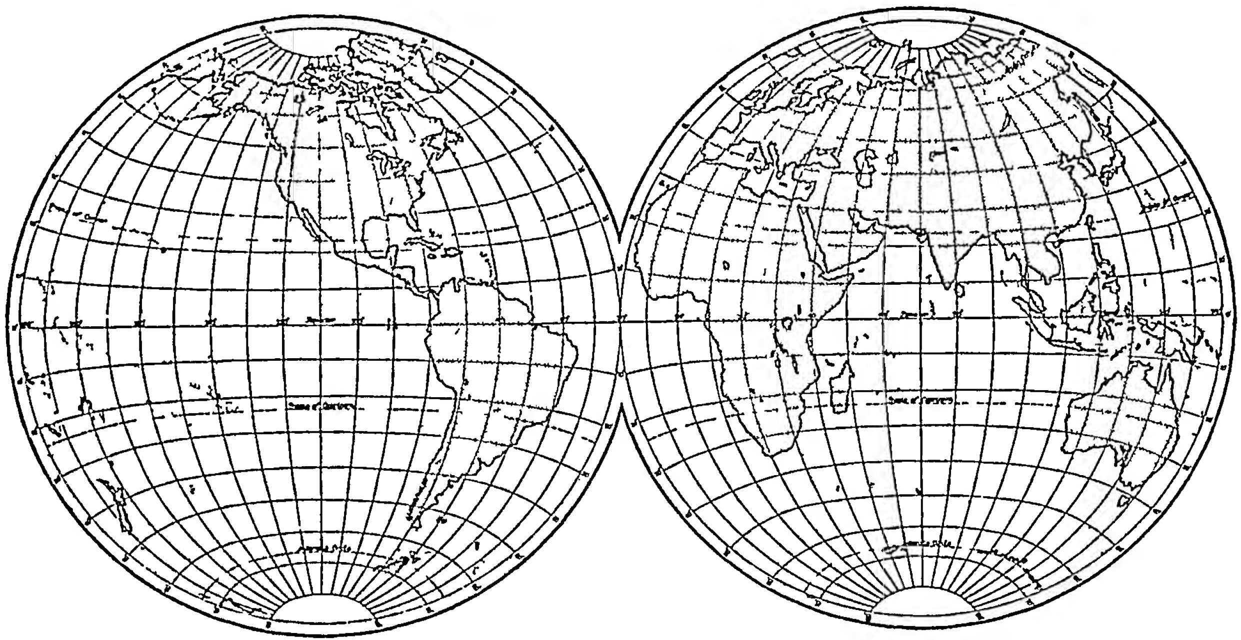

FIG 80 —THE HEMISPHERES, drawn on Lambert's Meridian Zenithal Equal-Area Projection

The gnomonic and the stereographic projections have one important property in common, they preserve correctly the azimuths or angular directions of places from the centre of the map, *i e*, the point of contact of the tangent plane On this account they are often called Azimuthal Projections They are also called Zenithal—a name which is generally preferred because it is easier to pronounce

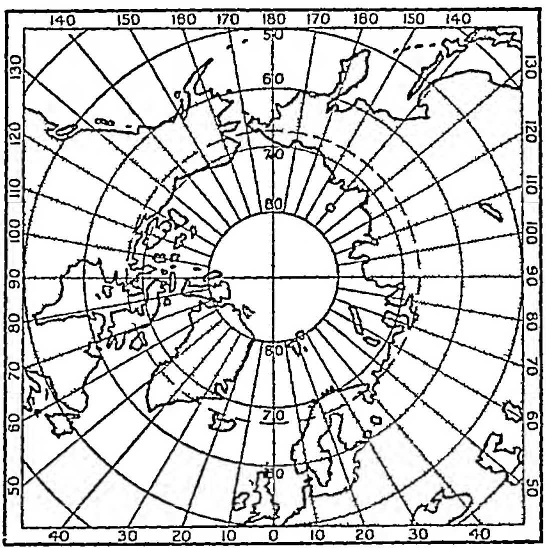

FIG 81 —LAMBERT'S POLAR ZENITHAL EQUAL AREA PROJECTION

Modifications of these zenithal projections are frequently used, they are made by adjusting the parallels to obtain some desired property The *Zenithal Equidistant Polar Projection* has the concentric circles representing the parallels *drawn* at the correct distances, from the centre of the map, according to scale The *Zenithal Equal-Area Projection* (Figs 37, 80 and 81) is drawn with the distances between the parallels so

arranged that the area enclosed by any given parallel is equivalent to the corresponding area on the globe The parallels in the case of the Polar Zenithal Equal-Area Projection are nearer to each other the farther one proceeds from the pole This Projection is known as Lambert's Zenithal Equal-Area Projection, it is widely used in atlases, especially with some point other than the pole as the centre of the map

The focus of the gnomonic projection is the centre of

FIG 82 —ORTHOGRAPHIC MERIDIAN PROJECTION

the sphere, that of the stereographic projection is a point on the opposite side of the sphere Now let the focus of projection be removed to an infinite distance, the lines of projection become parallel and the *Orthographic Projection* is obtained This is another variety of zenithal projection In the meridian or equatorial form (see Fig 82) the longitude lines are crowded towards the lateral edges of the map and the latitude lines towards the poles, hence there is much distortion of

shape This projection cannot be used for more than a hemisphere The *Orthographic Projection* (Fig 83) is sometimes used for *polar* maps showing only a few degrees from the pole, and also for equatorial regions involving no great extent of longitude, otherwise this projection is seldom used in geography

An ordinary stereographic projection shows enlargement of area at the edge of the map, whilst an Orthographic projection shows compression towards the edge, there must be a point somewhere between the stereo-

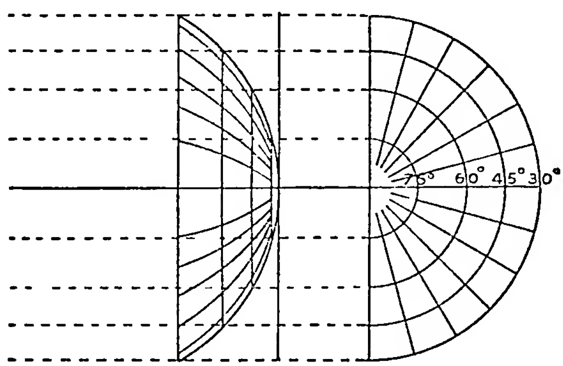

FIG 83 —ORTHOGRAPHIC POLAR PROJECTION

graphic focus and infinity which will give a minimum error In Sir Henry James' Projection the focus is at a point 1 367 times the radius of the sphere from the centre of the sphere Other foci of projection for different amounts of the surface of the sphere and for different positions of the section plane of projection vary between 1 367 R and 1 71 R These are called *Minimum Error Projections* (Fig 84)

Class 2 Cylindrical Projections—A cylinder can be opened out into a plane, it is said to be developable A cylinder is imagined to be tangent to the sphere, and points and lines on the sphere are projected upon it,

then the cylinder is opened out into a rectangle. A little consideration will show that in all ordinary cylindrical projections the meridians of longitude will appear as parallel straight lines—that is, they remain at equal distances apart instead of converging towards the poles.

The *Simple Cylindrical Projection* is illustrated by Fig 85, from which it will be seen that in high latitudes

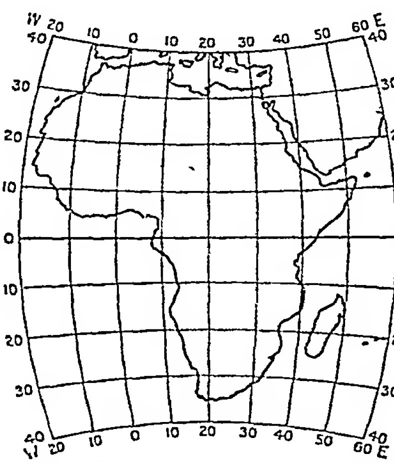

FIG 84.—AFRICA, ON A MINIMUM ERROR (CLARKE'S PERSPECTIVE) PROJECTION

The focus is distant 1·625 R

there is enormous exaggeration of latitude in addition to the usual longitude exaggeration. This projection is seldom used in practice.

In the projection just described the focus is the centre of the sphere. If instead of this the lines of projection are drawn from the *axis* of the sphere at right angles, these projection lines will obviously be parallel and will strike the enveloping cylinder at right angles. This

gives the *Cylindrical Equal-Area Projection* (Fig 86) A well-known theorem in solid geometry proves that the parallels thus drawn cut off equal areas from the sphere

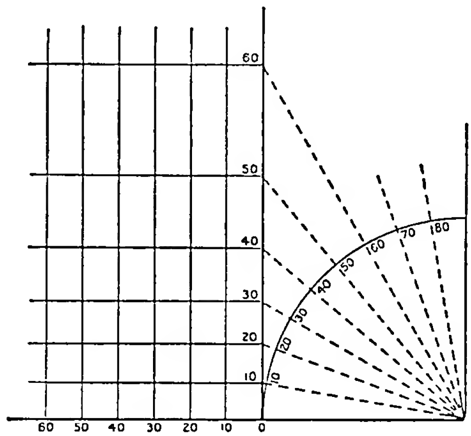

FIG 85 —SIMPLE CYLINDRICAL PROJECTION

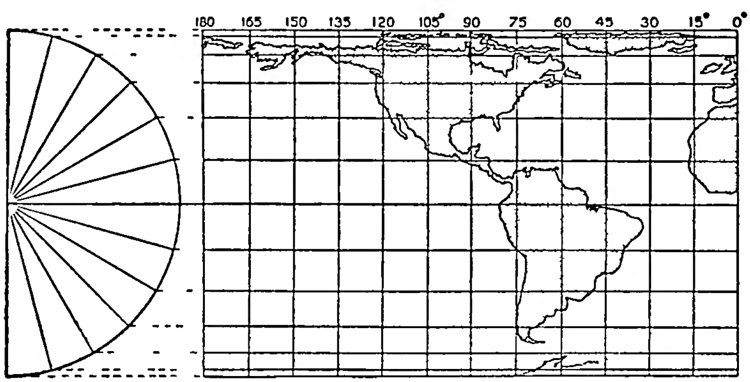

FIG 86 —CYLINDRICAL EQUAL AREA PROJECTION

and the circumscribing cylinder If the cylinder has the same height and the same diameter as the sphere, then the areas of the curved surfaces of the sphere and cylinder are the same This projection is therefore an

equal-area one The distortion in high latitudes is, however, so great that it is of little use except for a narrow belt in low latitudes

The *Equidistant Cylindrical Projection*—This is a conventionally drawn projection The meridians are

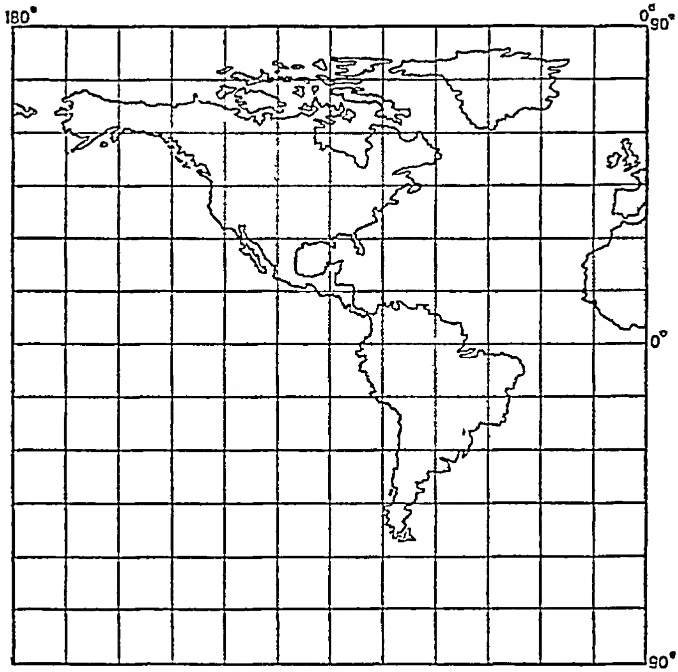

FIG 87—EQUIDISTANT CYLINDRICAL PROJECTION

drawn as in the other cylindrical projections, and the parallels are drawn at equal distances apart Assuming the earth to be a sphere, the " projection " becomes a rectangle made up of a series of squares (Fig 87)

The best-known cylindrical projection is the modified one so well known as *Mercator's Projection*, or the

Cylindrical Orthomorphic Projection In this graticule the exaggeration of latitude distance is made equal to that of longitude, this adjustment being the necessary condition of orthomorphism Round any given point the exaggerations of latitude and longitude are the same, for example, in 30° latitude the exaggeration of longitude distance is $\frac{2\sqrt{3}}{3}$, and the latitude is increased in the same ratio It is clear that here the exaggeration of area is $\left(\frac{2\sqrt{3}}{3}\right)^2, = 1\frac{1}{3}$ At 45° the exaggeration of both latitude and longitude is $\sqrt{2}$, and the area is therefore twice what it should be In 60° the actual width of a degree of longitude on the sphere is half its width at the equator, but owing to the parallelism of the meridians it is made of the same width as at the equator, or the exaggeration of longitude is 2 To maintain the principle of orthomorphism the latitude is increased in the same ratio—that is, multiplied by 2, and areas in this latitude will be four times what they should be In latitude 75° both latitude and longitude are 3 86 times their real lengths, and areas are $(3\ 86)^2$ or approximately 14 9 times their real size, this shows how very unsuitable a map on Mercator's Projection is for lands in high latitudes The reader should compare on such a map the areas of the three islands, Ceylon (25,400 sq miles), Ireland (32,000 sq miles), and Iceland (40,000 sq miles), and he will be impressed by the exaggeration of area in high latitudes Most emphatically this projection is unsuitable for a world map showing the British Empire

The merit of a Mercator map is that it is orthomorphic, and consequently directions from a point to any other are correctly represented Hence maps with this network are useful in navigation, and for the representation of the direction of winds and ocean currents on world

maps The shapes of local features, such as lakes, small bays, etc, are correctly represented, but a large country or a continent shows too great an exaggeration in its poleward parts Within 30° on either side of the equator the projection may well be used for maps such as ocean routes See Fig 88

The last modified cylindrical projection to be men-

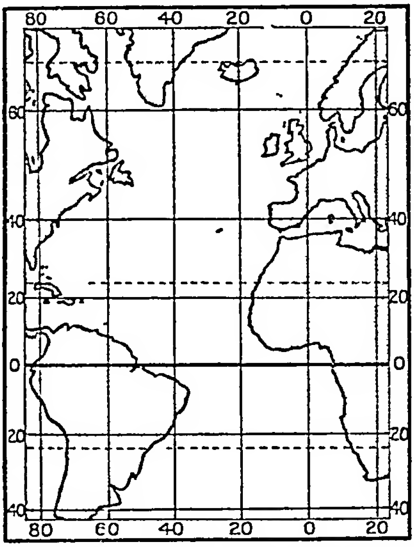

FIG 88 —THE ATLANTIC OCEAN ON MERCATOR'S PROJECTION

tioned is Gall's, where the cylinder is supposed to cut the sphere at equal distances on each side of the equator —for example, at 45° N and 45° S The cylinder of projection is thus let into the sphere, and the graticule is projected stereographically It is therefore known both as a cylindrical and a stereographic projection The latitude exaggeration is not so great as in Mercator's network, but in the part "within the sphere" the

longitude is constricted See, for example, the narrowed shape of Africa on world maps using this projection, and see Figs 22 and 23

Class 3 Conical Projections—A cone may also be developed or opened out into a plane, therefore the network of lines and the points on the sphere are often projected upon a cone Suppose a cone represented by *OPQ* is placed on the sphere touching it at *PQ* (Fig 89),

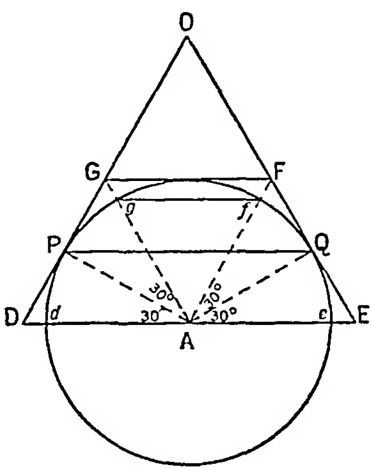

FIG 89 —SIMPLE CONICAL PROJECTION

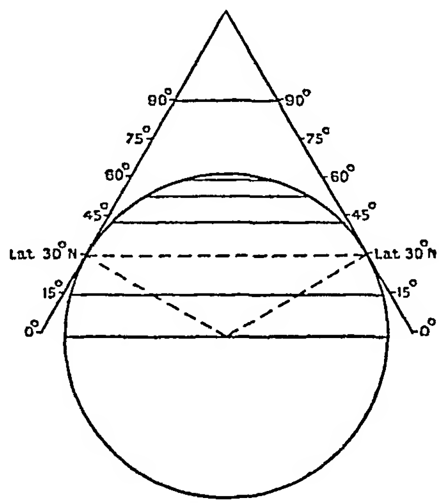

FIG 90—MODIFIED CONICAL PROJECTION

and having its apex on the axis of the sphere produced It is evident that the relative positions of points on the small circle *PQ* of the sphere will be correctly represented on the circular arc of the cone when it is opened out Let *PQ* be, for example, in latitude 30° N, then all points in that latitude will be correctly represented Draw *AF* and *AG*, making angles of 60° with the equatorial plane, cutting the sphere in *f* and *g*, the small circle *fg* on the sphere will be represented by the circle *FG* on the cone Similarly *d* and *e* on the equatorial diameter

will be projected as D and E on the cone, and the circle containing D and E on the cone will be the exaggerated representative of the equatorial circumference of the sphere In this simple case PQ is called the standard parallel, and in the case of an ordinary conical projection the meridians are lines drawn from points on this standard parallel to meet at the apex of the cone This simple conical projection is neither orthomorphic nor equal-area, it is rarely used in this unmodified form

The more usual conical projection with one standard parallel is modified by making the concentric parallels of latitude the correct distances apart Beginning at the point where the cone touches the sphere, points are marked off northwards and southwards at correct distances for, say, every 10° or 15° on the central meridian, and lines of latitude are drawn parallel to the standard parallel The meridians are drawn through the correct points on the standard parallel and at right angles to it It will be noticed that on this modified projection the pole is represented as a circle and is not at the apex of the cone (Fig 90)

In another modified conical projection two standard parallels are drawn at a correct distance apart, according to the length of arc between them (compare Gall's Cylindrical Projection) The projection is then the same in method as the simple one described above The scale is correct on the two standard parallels, between them latitude distance is diminished and outside them it is exaggerated This form of projection is more widely used than that with one standard parallel Several modifications are possible which depart from true projections If the exaggeration of latitude be made proportional to that of longitude, then the projection becomes orthomorphic, but if the exaggeration of longitude extension be compensated by a corresponding

decrease in latitude extension, the "projection" becomes an equal-area one This last projection is widely used

In all these conical projections, whether with one or two standard parallels, the latitude lines are parallel to each other and the meridians are straight lines at right angles to all the parallels An interesting modification as regards the drawing of the meridians gives Bonne's Projection, which is dealt with under Class 4

The Polyconic Projection —In this important modification we imagine a succession of tangent cones with their apices on the axis of the sphere produced A series of standard "parallels" or lines of latitude with different radii results, and these circles are no longer parallel to each other The meridians are not straight lines, but smooth curves passing through the successive latitude lines at the correct points The central meridian is a straight line at right angles to all the circles of latitude

The polyconic projection forms the basis of the International Map on the scale of 1 1,000,000, but in 1909 a modification was introduced by making some of the meridians slightly longer than the correct length The sheets cover 6° of longitude by 4° of latitude, and the meridians 2° E and 2° W of the central meridian of the particular map are made of their true length

The Rectangular Polyconic Projection —This modifies the conical projection still further The latitude lines are drawn as in the polyconic projection One of these is selected as a standard, and is divided correctly for the meridians, then the latter are drawn as curves passing through the points thus obtained and cutting all the other latitude lines at right angles This graticule (which is clearly far removed from a projection in the strict sense) has been much used by the War Office in recent years All such "projections" are constructed from tables

Class 4 "Conventional Graticules"—In this class the networks of lines of latitude and longitude are drawn according to some plan without any reference to "pro

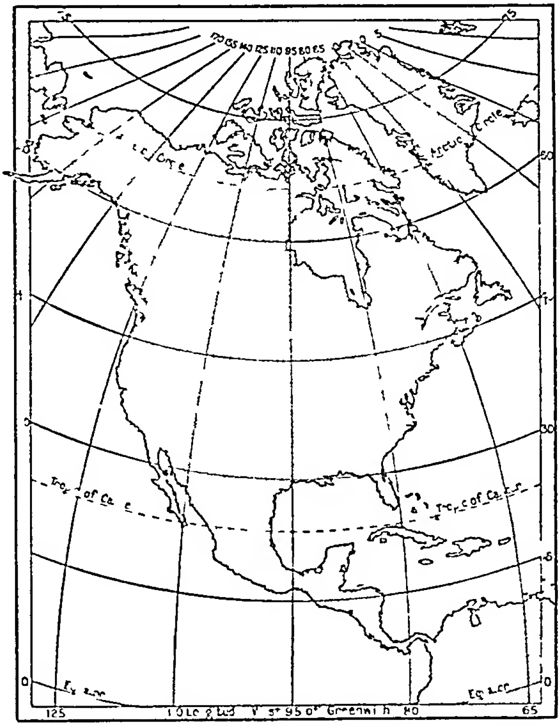

FIG 91 —NORTH AMERICA, DRAWN ON BONNE'S PROJECTION
The central meridian is 95° W, other meridians and parallels being at 15° intervals

jection" from either a focus or an axis, they are not strictly projections at all in the geometrical sense Four well-known examples of these conventional networks will be described here

Bonne's Projection—A standard parallel is first of all

drawn as in the conical projection, then the other parallels are drawn at true distances on the selected scale, north and south of the standard parallel The meridians of longitude are then drawn arbitrarily as follows suppose it is required to insert them at intervals of 15° of longitude Select one standard meridian which will be drawn at right angles to all the parallels Then from this standard meridian mark off on each

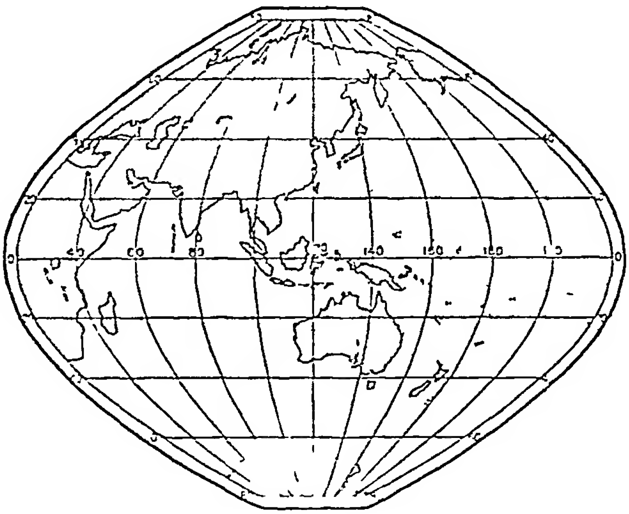

FIG 92 —SANSON-FLAMSTEED (OR SINUSOIDAL) EQUAL-AREA PROJECTION

parallel of latitude the correct longitude distance corresponding to 15° for that latitude Draw curves through all the points so determined, these curves represent the meridians The selected meridian cuts all the parallels at right angles, the standard parallel cuts all the meridian curves at right angles This is an equal-area projection which is very widely used (Figs 36 and 91)

The Sanson-Flamsteed Projection —Suppose in Bonne's Projection, instead of selecting a curved standard parallel

as developed on a cone, we take the equator as the standard and make all the other conditions as in Bonne's Projection, then the parallels will all become parallel *straight* lines and each meridian becomes part of what is called in mathematics a sine curve This projection is often called the Sinusoidal Projection, like Bonne's, of which it is a modification, it is an equal-area one and is very widely used, as will be mentioned later (Fig 59)

Mollweide's Homolographic Projection—This is also

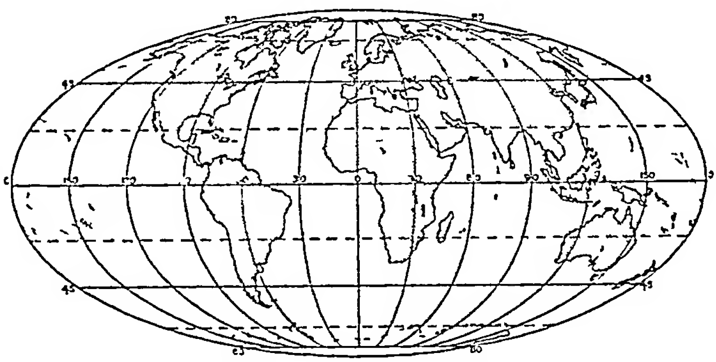

FIG 93—THE WORLD, ON MOLLWEIDE'S HOMOLOGRAPHIC PROJECTION

an equal-area projection which represents the whole earth as an ellipse The major axis, which is to represent the earth's equatorial circumference, is made twice as long as the minor axis which is to represent a meridian from pole to pole (In world maps the earth is usually taken as a sphere) The major axis will thus represent the equator and the minor axis the central meridian The other meridians are drawn as follows the true distances to the selected scale are marked on the major axis, and for each meridian an ellipse is drawn

through each of these points and the two poles The meridians 90° E and 90° W will obviously be semicircles (Fig 93)

The parallels of latitude are straight lines parallel to the equator, their position is determined by a somewhat difficult mathematical calculation The necessary values from which one can draw the network may be obtained from many books of mathematical tables

FIG 94 —GLOBULAR PROJECTION

With Longitude 75° E as central meridian and meridians and parallels at 15° intervals

It will be seen that the distances between the parallels decrease from the equator to the poles Compare with the Sanson-Flamsteed Projection, where the parallels are equidistant throughout

The Globular Projection —This is a network which is very easily constructed, and is occasionally used in atlases for maps of the world in hemispheres Its simplicity of construction is almost its only recommendation It is drawn as follows A circle is drawn

to represent each hemisphere, the horizontal diameter represents the equator and the vertical diameter the central meridian The equatorial diameter is divided into equal parts to represent degrees of longitude, the central meridian into corresponding equal parts to represent degrees of latitude The quadrants of the circumference are similarly divided The points thus obtained are used to draw arcs of circles which will represent meridians and parallels In Fig 94 the projection is drawn with lines of latitude and longitude at every 15° The reader will have no difficulty in following the construction

Some notes on the use of a few of the best known projections generally found in modern atlases

CLASS I —(1) *Lambert's Equal-Area Zenithal (Polar)* —This is often used for maps of polar regions The maps generally extend to 40° from the pole, but occasionally one is seen which takes in a hemisphere with the pole as centre The meridians are radial straight lines, and the lines of latitude are concentric circles whose distances apart diminish towards the edge of the map See Fig 81

(2) *Lambert's Equal-Area Zenithal (Meridian)* —This is frequently used for the world in hemispheres, the central points being on the equator, and at 70° E and 110° W respectively The equator and the central meridian are straight lines cutting each other at right angles The equator cuts the curved meridians at right angles, and the central meridian cuts the elliptical "parallels" at right angles This is a good projection for hemispheres, as the shapes of regions towards the edges of the map are not greatly distorted See Figs 37 and 80

(3) *Lambert's Equal-Area Zenithal (Horizontal)* — This is often chosen for maps of Asia, or the North Atlantic, or similar regions The distortion towards the edge of the map is less than if Bonne's Projection is used For a map of Asia the centre of the map may be at 40° N, 90° E

(4) *Zenithal Equidistant Projection* —This is a common network for maps of the polar regions The meridians are straight lines meeting at the poles, the parallels are concentric circles at equal distances apart It is a good projection if maps are not carried more than 40° from the pole

CLASS 2 THE CYLINDRICAL GROUP

(5) *Gall's Projection* —This is now very widely used for maps of the world, and for general atlas maps it is better than Mercator's Projection The exaggeration in latitude is not great up to 60° See Figs 22, 23 and 26

(6) *Mercator's Projection* —This is a network that is still in common use for maps of the world, and unfortunately for many maps where the great exaggeration of area in high latitudes is a serious drawback It is, of course, allowable for marine charts, and it is suitable for general maps of a not too wide belt on each side of the equator See Fig 88

CLASS 3 —(7) *The Conical Projections* —This is the most widely used class of projections for separate countries and for smaller continents or regions similar in size to Europe, *e g* the West Indies The modified conicals, with one or two standard parallels, are both in common use The parallels are arcs of concentric circles, and the meridians are straight lines at right angles to the parallels See Figs 89 and 90

(8) *The Polyconic and Rectangular Polyconic Projections* —These are commonly used for larger scale

maps of topographical surveys The lines of latitude are no longer parallel to each other The reader may be reminded that the International map is drawn on a slightly modified form of the Rectangular Polyconic projection

CLASS 4—CONVENTIONAL AND ARBITRARY PROJECTIONS

(9) *Bonne's Projection*—This is now one of the most widely used projections in modern atlases It is used most for North America, the United States, Canada, Australia, India, and sometimes for Asia and for Europe It is not nearly so suitable for Asia as the Zenithal Equal-Area Projection It is occasionally used for maps of the British Isles, and for parts thereof, but it does not seem to possess much advantage over the more commonly used conical projection with two standard parallels Probably it is the equal-area property which accounts for its use in these cases

Bonne's Projection may be recognised by the parallels being actually parallel and at equal distances apart, and by the peculiar curvature of the meridians The central meridian cuts all the parallels at right angles, the (selected) standard parallel cuts all the meridians at right angles See Figs 36 and 91

(10) *The Sanson-Flamsteed Projection*—This is the standard projection for Africa, South America, and sometimes for such maps as the Atlantic

The region should be cut by the equator and should not have a too wide extension in longitude, hence it is not very satisfactory for such maps as Oceania The parallels are all straight lines at equal distances apart, the meridians are curved lines, as in Bonne's Projection See Figs 20 and 92

(11) *Mollweide's Homolographic Projection*—This elliptical projection is now very common in atlases

and for wall-maps of the world Like Bonne's and Sanson-Flamsteed's, it is equal-area , the drawback is that peripheral parts are so greatly distorted in shape It has been used with good effect in some recent atlases for maps of hemispheres, where the distortion is not so great For this purpose the Zenithal Equal-Area (Meridian) would appear to be better, as the distortion in shape is decidedly less

The Mollweide Projection may be recognised by its elliptical meridians, and by its lines of latitude being parallel straight lines which are closer together towards the poles See Figs 21, 35, and 93

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APPENDIX

TABLE OF CHIEF IGNEOUS ROCKS

		According to Chemical Composition			
		Acid, over 65 per cent. Silica.	Intermediate, 55–65 per cent Silica.		Basic, below 55 per cent. Silica
			Sub acid	Sub basic.	
According to mode of origin or position with respect to earth's surface	Volcanic or Superficial Lavas	Rhyolites and Liparites	Trachytes and Phonolites.	Andesites.	Basalts.
	Minor intrusive Sills, necks, dykes, etc.	Minor acid intrusions Elvans.	Mica traps. Minettes, Porphyries, and Porphyrites		Dolerites
	Plutonic or deep-seated Large bosses and other large masses of deep seated origin	Granites.	Syenites	Diorites.	Gabbros.

Igneous Rocks may be classified according to their composition, and as the names in common use depend upon the chemical and mineral composition, it is necessary to indicate very briefly the basis of the classification The commonest chemical compound present in igneous rocks is Silica, or oxide of silicon, SiO_2 This constituent is comparatively easy to estimate by analysis, and hence it is used as a basis of classification Those rocks which contain a very large proportion of silicia are known as *Acid*, those with a relatively low proportion are *Basic*, and those with an intermediate proportion are known as *Intermediate*

Thus, by combining both the ultimate chemical composition and the mode or circumstance of origin, we may make a table which includes the best known kinds of igneous rocks, and which is sufficiently elaborate for the geographer

Table of the Systems of Sedimentary Rocks with some British and other Examples

Group.	System		Examples	Prominent Life forms
Cainozoic or Tertiary	Pleistocene and Recent		Alluvial deposits of the Fenlands River gravels Old sea beaches Glacial deposits Peat beds	Man and present day animals appear
	Pliocene	Neogene	Gravels, sands, etc , of East Anglia. Thick marine beds of the Apennines	
	Miocene		No undoubted British examples Swiss conglomerates of Rigi, etc	
	Oligocene	Palæogene	Sands, clays, etc , of Hampshire Basin Upper beds of Paris Basin Lower Fresh water Molasse of Switzerland	
	Eocene		Sands, gravels, clays, etc , of London Basin Lower beds of Paris Basin Nummulitic limestone of the Alps	Mammals become very common, and varied in type
Mesozoic or Secondary	Cretaceous		Chalk of Downs, Chilterns, Flamborough, etc Greensand, Gault clay, Wealden beds Quader Sandstone of Saxony Lower Flysch sandstones of Vienna Basin	Birds appear

Group	System	Examples	Prominent Life forms
MESOZOIC OR SECONDARY (*continued*)	Jurassic.	Limestones of Portland, Bath, etc Sandstones of North Yorkshire Oxford clay Shales and limestones of Whitby and of Lyme Regis Limestones, etc, of Jura, Plateau de Langres Ironstones of Cleveland, Lincolnshire, Northamptonshire, Wiltshire, Plateau de Langres Lorraine	Reptilean life very varied and in great profusion
	Trias or Triassic	New Red Sandstone of Cheshire and the Midlands Salt deposits of Cheshire. Limestones of the Tyrol	Mammals first appear
PALÆOZOIC (Upper)	Permian.	Red Sandstones of North Nottinghamshire Dolomitic limestone of Durham, Yorkshire, and Nottinghamshire. Some pebble beds of Midlands Zechstein of Germany Sandstones, shales, and limestones of Perm in Russia.	Reptiles appear
	Carboniferous	Sandstones, shales, and coal seams of the coal-measures of Britain, France, Belgium etc Oilshales of Scotland Millstone Grit of the Pennines Pennant Grit of South Wales Limestones of Pennines, North Wales Mendips, Central Irish Plain	Amphibia appear Plant life varied and profuse
	Devonian	Limestones, slates, etc., of Ilfracombe South Devon Cornwall Old Red Sandstone beds of Cheviots, Central and North East Scotland Limestones of Eifel and Middle Rhine.	Fishes very common

Group	System	Examples	Prominent Life forms
PALÆOZOIC (Lower).	Silurian	Sandstones, limestones, and shales of the Welsh Border Coniston Flags and Grits (Lake District) Kirby Moor Flags Limestones of Gothland Shales, etc., of Bohemia	Fishes appear
	Ordovician	Sandstones, shales, and some limestones of Central Wales and Snowdon Volcanic rocks of Borrowdale (Lake District) Skiddaw Slates Shales in Southern Uplands of Scotland Shales and limestones of Southern Scandinavia.	
	Cambrian	Slates, sandstones, conglomerates of North Wales Slates and quartzites of Nuneaton Rocks of various types in Malvern and Wrekin districts Durness lime stone in N W Scotland	All the classes of invertebrate animals present
	Pre Cambrian	Sandstones of Longmynd in Shropshire, and Loch Torridon in N W Scotland	Fossils only very obscure and doubtful
	Archæan	Schists, gneisses, quartzites of Highlands of Scotland, N W Ireland, parts of Anglesea, Charnwood Forest. Metamorphic rocks of Scandinavia, St Lawrence region of Canada	No undoubted life traces

QUESTIONS SELECTED FROM THE EXAMINATION PAPERS IN GEOGRAPHY SET BY VARIOUS WELL-KNOWN EXAMINING BODIES

THE student is recommended to spend considerable time in this series of questions It is hoped they will serve the double purpose of assisting him to fully understand and assimilate what he has read, and stimulate him to thought which may carry him beyond the limits of the book It is not pretended that every question may be fully answered from this book, and it is exactly those questions which are worth the more serious consideration of the student

A *study* of question 60 on an isothermal line—using a good map showing those lines—will help the student to grasp fully some of the most important factors of climate So also a *study* of the thoroughly good question 137 is one of the best possible exercises In studying a question such as 113, the student will be considerably helped by making a "graph" of the rainfall for the three places These are, of course, only examples To the keen student other methods will readily occur

To the student who wishes to see fuller collections of questions it may be pointed out that some of the series are published regularly in book or pamphlet form The papers set at Oxford Senior Local and Oxford Higher Local are published by the Oxford University Press, those set at the various London University Examinations are published *in extenso* by the London University Press, Ltd, St Paul's House, Warwick Square, London, E C—from whom they may be obtained

QUESTIONS

STRUCTURAL GEOGRAPHY

OXFORD SENIOR LOCAL

1 "Lakes are transitory features of a region" Explain carefully why this must be so What are the various economic uses of lakes? Give examples

OXFORD HIGHER LOCAL

2 Compare the distribution of land and sea in the Northern and the Southern Hemispheres State some of the consequences of these facts

CAMBRIDGE SENIOR LOCAL

3. Describe the physical characters of the west coast of Ireland, and point out any resemblances and differences between it and the west coast of Scotland

4 Describe and explain the characteristic features of the principal types of coast-lines, and mention an example of each

5 Describe the physical character of the coastal region of the United States between Florida and the Bay of Fundy, and show how it has influenced the progress of colonisation and subsequent development of the country

6 Describe the mountain systems of South America

7 Give some account of the Lakes of Asia

UNIVERSITY OF LONDON · MATRICULATION

8 Give an account of the Geographical distribution of active and recently extinct volcanoes Describe the characteristic features of a volcanic district

9 Give an account of the distribution of volcanoes in the Pacific region Describe the characteristics of some of the more important volcanoes of that region

10 Describe and explain, as far as you can, the physical character of the west coast of the mainland of Europe, from Southern Norway to Brittany (excluding the Baltic coast)

11 Describe the physical characters of the Mediterranean Sea and its northern coast Compare the Mediterranean Sea with the Gulf of Mexico

12 Describe, or show by a sketch-map, the position of the chalk hills around the London Basin on the north, west, and south Indicate the places where the main lines of railway cross this chalk rim

13 Give a description of the characteristics of the mountain systems of Europe

14 Give a description of the characteristics of the mountain systems of Asia

15 What are the principal types of mountains? Mention examples of each Explain, as far as you can, the way in which each type has been formed

16 Write an account of the physical geography of the Himalaya

17 Describe the physiography of the Highlands and Western Islands of Scotland

18 Describe the principal types of mountain structure and give illustrations of each

19 Explain the structure of the Weald, and its relation to the drainage system of the area

20 In what regions of the world does the drainage find no outlet to the sea? Describe the characteristics of one of these regions

21 Describe the characteristics of the principal types of lakes Mention an example of each type

22 Describe, and, as far as you can, account for the position of the chief lakes of Ireland, mentioning the rivers with which each is connected

23 Describe the conditions necessary for the formation of (*a*) a delta, (*b*) an estuary Illustrate your answer by reference to examples

24 In what ways have plains been formed? Describe the characteristics of extensive plains in Europe and North America

25 What is "loess"? What do you know of its distribution in Europe and in Asia?

26 Describe briefly the extent and character of the Continental Shelf on which the British Isles are situated, and state what advantages these islands receive from such a situation.

UNIVERSITY OF LONDON INTER SCIENCE, ECONOMICS

27 Correlate the coastal features of the Eastern States (U S A) with the character of the land behind them

UNIVERSITY OF LONDON INTER ARTS

28 Describe the Continental Shelf and discuss its economic importance

UNIVERSITY OF LONDON B A

29 Discuss, with illustrations, the importance of the conception of an erosion (or topographical) cycle in the study of land forms

30 Draw a map and sections of the Pennine Chain of England to show its limits, divisions, and shape Point out how the topography has determined the course of the chief railway routes across it

31 Describe and account for the shapes of the sides and bottoms of Alpine valleys, and the development of such a valley system as that of the Rhone basin above the Lake of Geneva or of the Rhine basin above the Lake of Constance

32 Describe the two great mountain nodes of Asia, and the courses of the mountain systems which meet in them

33 "Between the Bay of Biscay and the main streams of the Vistula is a succession of blocks and basins bordered on the north by lowlands which rise to the heights fringing the English Channel, the North and Baltic

Seas" Discuss this statement and show how far it can be justified

34. Compare the physical features of the Alps with those of the Scandinavian Highlands, and account for both resemblances and differences

35 Describe the character of the chalk-scarped ridges in the South of England, and of the gaps through them, noting the utilisation of these gaps as lines of movement, and the position of the more important gap towns Illustrate your answer by a sketch-map

36 Describe the structure and physical history of the north German Plain, and trace its influence upon the direction of the rivers which cross it

37 Write an account of the various types of Lake basins and give examples

38 Distinguish between the Atlantic and Pacific types of coast, and give any explanation you can

39 Compare North America, east of the Rocky Mountains, with Europe west of the Urals and north of the Alps, as regards physical structure and configuration

40 Describe the shape of the ridges and valleys and their general arrangement in such a mountain system as the Central Alps, and give as full explanation as you can of the phenomena described Draw plans, profiles, and sections to illustrate your answer

CLIMATIC GEOGRAPHY

OXFORD SENIOR LOCAL

41 Name and describe the planetary wind systems of the Northern Hemisphere What are the causes which modify the planetary circulation in Western Europe? What modifications occur (*a*) in January, (*b*) in July? How do you account for (*c*) a strong westerly gale in the English Channel, (*d*) a dry east wind in Norfolk? At what times of the year are these most likely to occur?

42 In the Southern Hemisphere the three Continents

have each an arid region near the West Coast Name the regions and state the causes of their aridity

43 What are the chief factors which determine (*a*) the winter temperature of the British Isles, (*b*) the rainfall of Southern Europe?

44 From West to East, Canada may be divided into three climatic regions differing both in temperature and in rainfall Where would you draw your dividing line? Describe in general terms the distribution of (i) the temperature, (ii) the rainfall of each region

OXFORD HIGHER LOCAL

45 What are the chief factors controlling the climate of South Africa? Explain fully why most of the rain falls during the warmer months of the year

CAMBRIDGE SENIOR LOCAL

46 What parts of the British Isles are (*a*) wettest, (*b*) driest, (*c*) warmest in summer; (*d*) coldest in winter, (*e*) of least range of temperature? How would you account for the differences?

47 The average January temperature of Cambridge is 38° F, of Cardigan 42° F The average July temperature of Cambridge is 63° F, of Cardigan 60° F The mean annual rainfall of Cambridge is about 25 ins, of Cardigan more than 40 ins Both of these towns are situated about 52° N Lat Account for these differences

48 The average January temperature of the Orkneys is about the same as that of the Isle of Wight (40°–41° F) but the average July temperature of the Isle of Wight is over 62° F, while that of the Orkneys is less than 55° F What explanation can you offer? Which of these places has the heavier rainfall and why?

49 Give some account of the differences in temperature and rainfall in different parts of the British Isles

50 Contrast the climates of Glasgow and Moscow as regards (i) summer temperature, (ii) winter temperature, (iii) rainfall, accounting for the differences that

are found Give the latitude of Moscow, and say what is the time there when it is noon at Greenwich

51 Describe and account for the characteristics of the Mediterranean type of climate, and mention the principal regions of the world in which that type occurs

52 Contrast and account for the climates of the east and west coasts of Canada

53 It has been pointed out that Japan has a very different climate from that of Britain, the European country with which it is most frequently compared Describe the climate of Japan, and how it differs from that of Britain Explain briefly the causes or conditions which determine the climate of Japan

54 Give some account of the climate of Cape Colony, mentioning any peculiarities in its rainfall What other part of Africa has a similar climate ?

55 Contrast the climates of the Cape York Peninsula and the Island of Tasmania, in both cases explaining the causes of the climate

56 Give some account of the climate of the southern part of India, with reasons for the facts you give

UNIVERSITY OF LONDON MATRICULATION

57 Give an account of the general arrangement of the winds on the surface of the earth between the Equator and 60° S Where are there periodic variations in the arrangements brought about by seasonal changes ? And why do they occur ?

58 Give an account of the winds and calms commonly experienced in the following regions —Doldrums, Trade Wind Regions, Roaring Forties, Horse Latitudes, and draw a diagram showing the positions of these regions upon the earth

59 How is temperature usually shown on a map ? Give a full account of the various steps by which you would accumulate data for a map of the July temperature in the British Isles

60 Trace the course of one important isothermal

line around the globe, and account for the principal peculiarities which it presents

61 What is an isotherm? How do the isotherms of Europe (excluding the British Isles) in winter differ from those in summer? Explain the difference

62 Describe and account for the characteristics of (*a*) a Mediterranean climate, (*b*) a monsoonal climate Give the geographical distribution of each type of climate

63 Discuss fully the fundamental considerations affecting the climate of India

64 Describe and account for the rainfall of South-East Asia

65 Contrast, and explain, the climate of the lands that border the opposite sides of the Atlantic between 51° N and 60° N

66 Contrast with as much detail as possible the climate of the east coast of Australia with that of the west coast, giving the causes of any differences you mention

67 Compare the climate of Newfoundland and Vancouver Island Account for the differences

68 Describe and account for the distribution of rainfall in India

69 Describe, and account for, the distinguishing features of the climate of Ireland

UNIVERSITY OF LONDON. INTER SCIENCE, ECONOMICS

70 Compare the climates of England and New England, and explain both the resemblances and the differences

71 State the essential features of a monsoon climate, and illustrate their effects from (*a*) China and (*b*) Burma

UNIVERSITY OF LONDON. INTER ARTS

72 What factors determine the temperature of a region? Illustrate your answer by reference to some

definite country and its temperature both in summer and in winter

73 Contrast the distribution of temperature over the British Isles in summer with that in winter, and give the causes of the contrasts

74 Locate, and account for, those areas in the world which have typical summer drought and winter rains

75 Where, and why, do you find "Mediterranean" climates outside the actual Mediterranean basin?

UNIVERSITY OF LONDON B A

76 What are the principal effects of the presence of water or water-vapour in the atmosphere, and of the changes in the condition of water or water-vapour? Intimate parts of the world where the effects referred to are very marked

77 Mention parts of the world with a more or less elevated seaboard where the climate is (*a*) very dry, (*b*) very wet Explain the differences between the two

78 Illustrate from North and South America the precise climatic variations due to the movements of the wind system with the sun

79 Analyse carefully the climates of the following regions and account for the resemblances and differences between them (*a*) Nigerian Sudan, (*b*) the Eastern Deccan, (*c*) Southern Japan

NORTHERN UNIVERSITIES JOINT MATRICULATION

80 Describe and account for the distribution of temperature over the British Isles in summer and winter respectively

81 What parts of the British Isles have (*a*) the rainiest and (*b*) the most equable climate? In each case state why this is so

BOARD OF EDUCATION, CERTIFICATE AND PRELIMINARY CERTIFICATE

82 Why are Western Europe, Eastern Europe, and the Mediterranean lands considered to be distinct natural regions? Name the countries included in each of these natural regions and explain to what their distinguishing features are due

83 In what parts of the world does a division of the year into four seasons seem inexact and unsuitable? What division would you make in these cases?

BIOLOGICAL GEOGRAPHY

OXFORD SENIOR LOCAL

84. "Grasslands are usually those regions which are subject either to (*a*) great extremes of temperature or to (*b*) long droughts" Give an example from the British Empire of (*a*) and of (*b*) In each case briefly describe the climate, and the products resulting from these conditions State as accurately as possible the positions and limits of the areas you select

85 Select an important wheat-growing region in Canada State as fully as you can the reasons why wheat is largely produced in it

OXFORD HIGHER LOCAL

86 Explain fully why the central part of North America is remarkable for (*a*) the great variety of its agricultural products and (*b*) the certainty of the crops

CAMBRIDGE SENIOR LOCAL

87 Give an account of the zones of vegetation (in order from north to south) in Russia, and state the natural products of each

88 Give an account of the vegetation, distribution, and economic importance of tropical forests in South America

89 Describe the climatic regions of Australia Mention the vegetable and animal products which are characteristic of each region

90 Give an account of the relief, climate, and vegetable products of the Deccan

91 Name (*a*) the principal wheat-growing district, (*b*) the principal sheep-rearing districts, and (*c*) the principal cattle-rearing districts in England State the natural conditions which favour wheat-growing, sheep-rearing, and cattle-rearing in the districts you name

92 Describe the physical character, climate, and vegetation of the great plains of Canada

93 Into what vegetation belts may Russia be divided? Account for them and broadly indicate their limits Distinguish between the western and eastern portions of the southern belt, and give reasons for the difference

94 Draw a map of Australia and indicate the chief physical features Divide the whole area into (*a*) forest-land and land affording good cattle pasture (*b*) land suitable for sheep pasture, and (*c*) desert

95 In what regions of Asia are (*a*) tea, (*b*) rubber, (*c*) rice, extensively grown? Describe the conditions which favour the cultivation of each

96 In what parts of North America are (*a*) cotton, (*b*) maize, (*c*) sugar-cane, extensively grown? Give an account of the conditions which favour the production of each

UNIVERSITY OF LONDON MATRICULATION

97 From what parts of the British Empire do we obtain (*a*) wine, (*b*) cotton, (*c*) tobacco, (*d*) silk, (*e*) furs? Mention the climatic and other conditions necessary for the production of any three of these

98 Describe and explain the succession of belts of climate and vegetation in Russia from the White to the Black Sea

99 Describe and explain the succession of belts of climate and vegetation in North America from the Arctic Ocean to the Gulf of Mexico

100 State and account for the sources (excluding North America) from which the United Kingdom imports its chief supplies of meat

101 Describe the distribution of temperate forests, and compare their importance with that of tropical forests

102 Give an account of the relief, soil, and climate of the south-eastern United States with reference to the production of cotton

103 Explain the relation of the climate to the typical vegetation of (*a*) France, (*b*) Egypt, (*c*) Argentina

104 Locate, classify, and account for the chief areas of natural forest-lands in the World

105 Discuss, with special reference to causes and results, the distribution in Europe of the olive, sugar-beet, and wheat

106 State and account for the distribution of rice in the North Temperate Zone

107 Give a full account of the conditions that favour the production of wheat on a large scale, and state the chief areas in which it is so produced

108 What conditions are necessary for the successful cultivation of cotton? State accurately the areas in which it is produced Through what port or ports is the produce of each area exported and to what destination does it mainly go? In what areas has production increased considerably of late?

109 What are the approximate limits between which the great forest-belt of the Temperate Zone is found? Say what you know of the character of the forest, and mention the chief forest products

110 In what districts of the British Isles are (i) potatoes, (ii) flax, (iii) hops chiefly grown? Describe the conditions which render the districts you mention particularly suitable for such cultivation

111 Describe, and account for, the position of the desert regions of the world

112 From what plant is cocoa obtained? In what regions and under what climatic conditions is the plant grown? What other important commodities are grown in the same region?

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113 The figures below state in inches the average rainfall for each month of the year at the places named —

	Jan	Feb.	Mar	Apr	May	June.	July	Aug	Sept	Oct.	Nov	Dec.
Haiderabad (Sind)	0 2	0 1	0 1	0 2	0 1	0 4	2 8	3 2	0 8	0 0	0 1	0 0
Nagpur	0 6	0 4	0 6	0 5	0 8	8 8	13 3	8 9	7 8	2 3	0 4	0 5
Madras	1 0	0 3	0 4	0 6	2 2	2 1	3 8	4 4	4 7	10 8	13 7	5 1

Explain the differences indicated by these figures, and point out how differences in climate affect the condition of agriculture in the regions for which the places named are typical

114 Give an account of the climatic and other geographical conditions controlling the distribution of the principal vegetable fibres other than cotton

115 Mention the five principal regions which supply the United Kingdom with wheat or wheat-flour or both, and state the circumstances which bring about the great fluctuations from year to year in the relative amounts derived from the different regions

116 Discuss the potentialities of Nigeria as a cotton-growing country

117 State, and account for, the distribution of the chief flax-growing areas, distinguishing roughly the specifically " oil " from the specifically " fibre " areas

118 Discuss, with special reference to the British Isles, how far the productivity of land depends on geological formation

119 Discuss the character of the equatorial type of climate, and compare the economic condition of the various lands between the Equator and about 10° S

120 Explain, with reference to climate and soil conditions, the distribution of the chief types of vegetation in European Russia

121 What are the essential conditions of forest growth? What are the important differences between temperate and tropical conditions?

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122 Describe the essential geographic conditions involved in the distribution of forest, and estimate the relative value of temperate and tropical forests

123 How far, and for what reasons, can you class the Amazon basin and the Congo basin together as natural regions?

124 From what parts of the world is rubber obtained at present? Describe the conditions under which it is grown, and discuss the prospects of an increased output

125 Discuss the relation between the physical structure, climate, and natural vegetative regions of Russia

UNIVERSITY OF LONDON B A

126 Show how an arid and hot climate controls the character of land forms and the nature of vegetation

127 Describe and explain the changes in the general character of the vegetation which would be met with in a journey across Africa from the Cape to Cairo

128 Describe and explain the characteristics of desert and semi-desert vegetation Point out the economic value of this vegetation, if any

129 Compare and contrast the natural regions of Australia with those of Africa south of the Equator

130 Compare Central Canada and Western Siberia with regard to (*a*) the production of wheat, (*b*) forest industries

131 Locate, account for, and describe the typical features of the chief areas of savana in the world

132 Discuss the geographical distribution of sheep and cattle

133 What are the conditions required for the growth of cotton? Consider carefully the possibilities of a greatly increased supply from Africa (excluding Egypt)

NORTHERN UNIVERSITIES JOINT MATRICULATION

134 Describe the natural vegetation that is typical of the regions with a climate like that of the Mediterranean region, and show how the most characteristic plants are adapted to the climatic conditions

135 Into what climatic regions would you divide Canada? State the essential characteristics of each division

136 Name the chief wheat-producing areas of the world, and in regard to each give the time at which the harvest occurs and the reason why the harvest comes at that particular time

BOARD OF EDUCATION CERTIFICATE AND PRELIMINARY CERTIFICATE

England	Total Area.	Uncultivated Land	Ploughed Land	Pasture Land
East & N E	7 4 million acres	1 2 million acres	4 2 million acres	2 0 million acres
S E and E Midland	7 2 " "	1 7 " "	2 2 " "	3 3 " "
W Midland and S W	8 0 " "	1 7 " "	2 1 " "	4 2 " "
N & N W	9 7 " "	3 5 " "	1 6 " "	4 6 " "

137 What can be learned from the above table concerning the agriculture of each of the four divisions of England? To what causes are the differences due?

138 Explain how seasonal changes of warmth and rainfall are indicated by the chief vegetation zones of Europe?

139 Bread and butter are two of the principal foodstuffs of civilised man Show by reference to the great wheat and dairy lands of Europe what physical and climatic conditions are necessary to the production of these articles of diet on a large scale

140 Into what natural regions would you divide either Canada or Australia? State clearly the principles upon which your division is based

141 What parts of the British Empire lie within the Tropics? What common features and differences of climate and vegetation do they exhibit?

142 Give an account of the forest regions of Asia, explaining the causes which have produced them What use is made of the timber which they grow?

143 Taking Europe and Africa as one land mass, compare its physical features, climatic zones, and characteristic animals and plants with those of the continents of America (North and South)

HUMAN GEOGRAPHY, ECONOMIC GEOGRAPHY, AND MORE GENERAL QUESTIONS

OXFORD SENIOR LOCAL

144 Describe and account for the climate and chief occupations in (*a*) California, (*b*) Cuba

145 Show how geographical conditions hindered the exploration of Africa

146 Describe and account fully for the seasonal distribution of rainfall over the Australian continent Show how far rainfall determines occupations in the different parts of the Australian Commonwealth

147 Divide the United States east of the Rocky Mountains into natural regions

Describe and account for the climate of the south-east States, and show how far it determines the chief products of the region

148 What are the chief requirements for a commercial seaport?

149 Give two examples of products which are manufactured at a considerable distance from the source of supply State fully the conditions under which the raw material is obtained in each case, and the reasons for the position of the manufactory

150 Give an example (*a*) of a region where there is

a population largely engaged in agriculture, (*b*) of a region where most of the people dwell in towns Describe the two regions you select and account for the facts

OXFORD HIGHER LOCAL

151 Describe fully, and account for, the characteristic features of the equatorial type of climate Name a large land area where this type of climate prevails What useful commodities does the area produce?

152 Give some examples illustrating the fact that a seaport may be either favourably or unfavourably affected by improvements in methods of (*a*) land transport or (*b*) sea transport Discuss the examples you give

153 State and explain the conditions which have made south-eastern Asia the habitation of so large a proportion of the human race

CAMBRIDGE SENIOR LOCAL

154. Describe the delta of the Rhine, giving (*a*) its position and extent, (*b*) its physical characteristics, (*c*) its vegetable products, (*d*) its towns

155 Describe the positions and character of the Llanos, the Selvas, the Pampas, the Falkland Islands, and Lake Titicaca

156 Give some account of the Black Earth Region, the Karst, the Landes, the Mer de Glace, the Riviera, the Tyrol

157 Describe the following, saying in what parts of Africa examples of each are to be met with —kloof, oasis, shott, sudd

How would you account for the increased prosperity of Egypt in recent years?

158 Describe and explain the origin of (*a*) the Colorado Cañon, (*b*) the Chinook Winds, (*c*) Niagara Falls Give a brief description of (*d*) Jamaica, (*e*) Trinidad

159 Write an account of (*a*) the position and extent,

(*b*) the climate, (*c*) the physical features of the desert region of Australia

160 Describe the desert regions of America and account for their positions Name any articles of commerce that are obtained from them

161 What parts of Asia produce (*a*) tin, (*b*) tea, (*c*) silk, (*d*) camphor, (*e*) teak ?

162 Give some account of the position, extent, and character of the deserts of Africa, and explain their origin

163 What districts in Africa produce (*a*) ivory, (*b*) wine, (*c*) coffee, (*d*) wool, (*e*) cotton ?

164 From what parts of Central or South America does Great Britain import (*a*) mahogany, (*b*) nitrates, (*c*) rubber, (*d*) sugar, (*e*) wheat ?

165 What is meant by the statement that the Sahara, and not the Mediterranean, really separates Europe and Africa ? Support this statement by reference to the climate and productions of Mediterranean Africa

166 A population map of the British Isles indicates a dense population in (*a*) South Staffordshire and portions of adjoining counties, (*b*) a portion of South Wales What industries give employment to these large populations in the above districts ? Show the connection between the industries and the natural advantages in each case

167 What are the most striking features in the river system and coast-line of Australia ? Of what races does the present population of Australia consist ? How do you account for their presence there ?

168 The attraction of the towns, of which we hear so much, is really the attraction of minerals Consider how far this statement is true, illustrating your remarks by examples from Great Britain and Ireland

UNIVERSITY OF LONDON MATRICULATION

169 Contrast the climatic conditions on the two sides of the Irish Sea and explain the difference Point out the chief geographic causes which have influenced

the nature of the occupations pursued east and west of the sea

170 Give instances to show how far the commercial position of a country depends on its productions, geographical position, climate, contour (coastal outline), and relief

171 Point out the chief regions of dense population in England, and in each case show the chief causes to which the density is due

172 Compare the situation and configuration of Western Europe and Eastern Asia Account for the differences in the climate, productions, and trade of the two areas

173 Take examples from the United Kingdom to show the relationships existing between the position of large towns and (*a*) water supply, (*b*) mineral resources, (*c*) vegetable products, and (*d*) transport routes

174 Tabulate the principal areas from which the following commodities are obtained —wheat, maize, steel, salmon, beef What special facilities are required in the case of each commodity for the carrying on of a large trade ?

175 Divide Russia in Europe into natural regions, and describe briefly the climate, the chief occupations of the people, and the natural products of each region

176 Explain what are the most important marks of "Race," and describe the distribution of the chief races in Europe

177 State and account for the distribution of textile industries (other than cotton) in Scotland and Ireland

178 Discuss the geographic contrasts between the south-east and the north-west areas of the British Isles

179 Discuss, with examples, the conditions favourable to the growth of a great port, with examples from Europe.

180 In what respects can you reasonably compare the British Isles with the Japanese ?

181 Where in the British Isles is salt found in considerable quantities ? How is it obtained ? And what industries have grown up in connection with the various "fields" ?

182 Describe and compare the past and the present distribution of important wool industries in Great Britain

183 Describe the geographical conditions of the Steppe, and show their influence on life there

184 Mention four or five areas of dense population in the continent of Europe State briefly why so dense a population should have gathered in each of the areas you mention

185 Explain fully the geographical conditions which have controlled the growth and importance of London

186 State the regions or centres in Europe in which silk is (*a*) produced, and (*b*) manufactured, in each case giving reasons for the localisation of the industry

UNIVERSITY OF LONDON. INTER SCIENCE, ECONOMICS

187 Give an account of the distribution of the iron and steel industry of the United Kingdom Indicate the conditions which have in recent years affected the relative importance of the different seats of that industry, and those which are tending to bring about further changes at the present time

188 What are the natural economic regions of Australia, and how far are they controlled by configuration, climate, and facilities for trade ?

189 Show how modern developments in the treatment, handling, and transport of commodities have affected our trade in food products within the last thirty years

190 What do you understand by a winter monsoon ? Illustrate from Asia the effects of such a wind on human and plant life

191 Examine the various conditions making for or against the increased use of water-power in the near future

192 Indicate the probable " home " of each of three great races,—White, Black, and Yellow,—and show how the climatic factors in each case were favourable to the development of the particular race in the particular area

193 Compare the economic importance of the various areas in the world which have a "Mediterranean" climate

194 Give an account of the distribution of iron-ore in Europe, with special reference to (*a*) output, (*b*) fuel for smelting purposes

195 Discuss the distribution of tea and coffee-planting, taking into account physical features, climatic conditions, labour supply, and access to markets

UNIVERSITY OF LONDON INTER ARTS

196 What geographical conditions have favoured the localisation of the cotton industry in Lancashire?

197 Discuss the distribution of sources of power other than coal, in Eurasia

198 Discuss the value of tropical possessions to a State in the temperate regions

199 Give an account of the three most important races of Europe, indicating their distinguishing characteristics and the regions now occupied by the races How far are the people of Britain representative of these races?

200 Describe and account for the typical industries of the following regions —The Great Karroo, Northern Nigeria, British Guiana, British Columbia

UNIVERSITY OF LONDON B A

201 Discuss instances in which the localisation of manufacturing industries has been largely determined by (*a*) local supplies of raw material, (*b*) local supplies of labour without local sources of power, and (*c*) a large local market

202 Describe, in some detail, the morphology of *either* the Central Plateau of France *or* of Bohemia and its surrounding highlands, and show how it has controlled the distribution of population

203 Account for the existence of hot and of cold deserts, and illustrate the effects of each on the character and occupations of "desert" people

204 What are the fundamental conditions affecting

the climate of India? And what are their special economic results?

205 What geographical causes have given the United States predominance in the raw-cotton market?

206 Compare the conditions determining the climate of the British Isles with those determining that of Japan, and trace the effects of climate on the economic activities of the two countries

207 How do you explain the fact that civilisation has developed in Africa to a less extent than in Asia?

208 Compare the distribution of the rainfall in Australia and New Zealand Consider the causes of difference, and the chief results on the density of population and the economic activities of the people

209 Describe the characteristics of an Alpine valley and ridge, paying attention to topographical features, climate, vegetation, and human activities and settlements

210 Discuss the line of elevation which forms the land edge of the Indo-Pacific basin, with reference to

(*a*) Volcanic and seismic phenomena
(*b*) Political and economic developments.

211. Summarise the arrangement of the chief ranges which radiate from the Pamirs Estimate their relative importance (*a*) climatic, (*b*) political

212 Discuss the geographical conditions affecting the position and development of towns, drawing your illustrations from the British Isles and the United States

213 Examine the utilisation of different types of grassland by peoples at various stages of civilisation

214 Illustrate the control exercised by the Alpine system on human intercourse (*a*) in past history, (*b*) at the present day

NORTHERN UNIVERSITIES JOINT MATRICULATION

215 State what you know of the development of the woollen industry in England, and show how geographical conditions have affected its location at different times

216. State the situation of three important manu-

facturing regions of the former German Empire, in each case name the chief products, and show why the particular industries became important in that region

217 What are the main features of the climate of the temperate grasslands? Explain the causes of such climate, and its effects on (*a*) the natural vegetation, and (*b*) the occupations of the people of these regions

218 State briefly how far geographical conditions have favoured the concentration of so much of the population of the globe in South-eastern Asia and in Western Europe

219 Name two regions in the United States where each of the following are typical products, and in every case point out the natural advantages for such production —oranges, tobacco, cotton manufactures, timber, gold

220 State as precisely as possible the position and extent of the districts which are the most important European sources for the supply of horses, petroleum, iron-ore, and wheat Explain particularly to what extent climatic conditions or facilities for transport favour these products in each case

221 How far do physical features account for the difference of economic development between the east and west of Great Britain? Compare their influence on such development in the sixteenth and nineteenth centuries respectively

222 Give some account of the distribution of sugar growing throughout the British Empire

223 Discuss the effect of climate upon manufactures Illustrate your answer by reference to the United Kingdom and the Colonies

224 Give some account of the varying density of population in different parts of British India, and state the causes which account for the greater density in certain districts

BOARD OF EDUCATION CERTIFICATE AND PRELIMINARY CERTIFICATE

225 What circumstances have favoured the development on a large scale of the following industries at

certain centres in North America —engineering, corn-milling, paper-making, fruit-growing ?

226 Explain the following statement as applied to modern Egypt "With the Nile regulated and controlled by an immense system of reservoirs and dams, with a fellâhin freed from excessive taxation and given an equitable judicial system, with a network of light railways rendering the produce of the country accessible to foreign markets, Egypt was never more prosperous and its future was never so bright "

227 From the point of view of economic geography, and particularly in relation to import and export trade, compare

(*a*) Port Said with Rotterdam
(*b*) The Congo with the Danube.
(*c*) Abyssinia with Switzerland
(*d*) Khartoum with Coblenz or Mayence
(*e*) Genoa with Port Sudan or Suakin

228 It is usual to treat the portions of Europe and Africa which border upon the Mediterranean Sea as a distinct geographical region What characteristics justify this treatment ? Illustrate the economic importance of the Mediterranean Sea (*a*) in the period B C, (*b*) in the Middle Ages, (*c*) since the opening of the Suez Canal

229 Geography deals largely with climatic conditions and their effect upon man Show the truth of this statement by contrasting the "geography" of Labrador with that of the Ganges Valley *or* the "geography" of the Sahara with that of the West Indies

230 Show how the need for interchange of production has led to the establishment of well-marked trade connections between ports in the British Isles and North America

231 Locate the chief industrial areas of Scotland and Ireland contrast their natural resources, and show how far these explain their respective manufactures

232 Contrast India with South Africa, or New Zealand with British East Africa, as regards relief,

rainfall, and natural productions Give reasons for the contrasts you mention

233 Arid plains and steppes are found in their greatest extent either in the Trade-wind belts or in vast continental interiors Wherever they occur, they present the same characteristics of land-surface and natural products, and impose on their inhabitants similar habits and modes of life

Give reasons for the occurrence of these areas in the regions mentioned, state the characteristics referred to, and show how environment has influenced the homes and settlements of the people

234 Compare the agricultural products and industries of the Central Lowlands of Scotland with those of the Central Plain of Ireland, in order to show how physical conditions have determined the relative commercial importance of these two regions

235 During the Middle Ages England was chiefly an agricultural country, but by the end of the eighteenth century had become the leading manufacturing country of the world What effects did this great change have by the middle of the nineteenth century (*a*) upon the growth of towns, (*b*) upon the iron industry, (*c*) upon the imports of the country ?

236 Contrast Iceland with Sicily in respect to relief, rainfall, and natural products To what causes do you attribute the differences you mention ?

237 Write an account of the former Austro-Hungarian Empire, bringing out the physical nature of its component parts and the differences in race of its inhabitants

238 To what causes would you ascribe (*a*) the distribution of population in Australia, (*b*) the importance of Singapore and San Francisco, (*c*) the present influx into the Canadian North-West, and (*d*) the constantly recurring danger of famine in India ?

239 "River valleys tend always to be centres of population" Why is this generally true ? Apply the statement to three of the following rivers —St Lawrence, Amazon, Euphrates, Indus, Murray, and Yukon

Some additional questions selected from those which the author has proposed to his own students These questions are of Higher Certificate, Intermediate, Pass Degree, and Diploma Standard

STRUCTURAL GEOGRAPHY CHANGES IN THE LITHOSPHERE

1 Give a brief summary of the modern doctrine of isostasy and the facts on which it is based

2 What exceptions can you quote to the generalisation that volcanoes occur on the continental margins ?

3 Summarise your knowledge of the known plateau lavas, including what is known of their age and of their petrographical character

4 Give an account of, and institute a comparison between the work of wind and running water, and especially mention their effectiveness in different types of regions

STRUCTURAL GEOGRAPHY LAND-FORMS

5 Describe any one of the great Shield Lands, and give an account of its economic resources

6 Classify the chief groups and ranges of Europe according to type and approximate geological age

7 What is a " river terrace " ? Explain the frequent occurrence of series of river terraces at different levels in so many river valleys

8 Write an essay on the formation of deltas

9 Describe the chief scenic features which are especially characteristic of an upland region which has been recently glaciated

10 Describe the course of events through which a region has probably passed which is now occupied by a great continental plain Wherever possible refer to concrete examples by way of illustration

11 Two long ribbon lakes lie in the same glen and are separated from each other by an alluvial fan made by mountain torrents The rocks of the glen are rounded and scratched as by glaciers, and a moraine

forms the dam at the lower end of the lower lake Describe the events which have produced these land-forms and conditions

12 Select one of the following pairs of contrasted regions

(a) The Cross Fell Block—the Vale of Eden,
(b) The Craven Highlands—the Craven Lowlands,
(c) The "High Peak"—the "Low Peak" (Derbyshire,

and write the physical history of the two parts concerned

OCEANOGRAPHY

13 Compare the Baltic and Mediterranean Seas, as to depth, form of coasts, temperature, and chemical composition of their waters

14 What is the importance of the Continental Shelf in connection with food supplies obtained from the seas?

15 Describe the general tidal phenomena experienced in any important port of which you have personal knowledge

16 Summarise the chief features of the movements of the surface waters in the Indian Ocean

17 Discuss the possibility of adding considerably to our food supplies from Arctic and Antarctic Seas

18 How far do the Arctic and Antarctic Oceans influence physical conditions in the Atlantic Ocean?

CLIMATIC GEOGRAPHY

19 What exception may be taken to the term "continental climate," as commonly used? Discuss the use of the term in the light of the following data

	Average Temperatures			
	January	April	July	October
Peking	23 5	56 8	78 9	54 4
Manaos	78 5	78 2	78 8	80 1

N B —Peking is at the edge, Manaos in the middle of a continent

20 Discuss the precise meaning which should be given to the terms tropical and equatorial as applied to climate, illustrating your discussion by reference to specific regions

21 Compare the successive general temperatures throughout the year at Holyhead and Moscow, and add such explanations as you think necessary

22 Account as fully as you can for the rainfall of Quebec and Ottawa being so equally distributed throughout the year Compare the St Lawrence region with the shores of the Sea of Okhotsk in this respect

23 Divide North America into Climatic Provinces and sub-Provinces [1]

24 Compare the climates of Ceylon and Tasmania, and those of Madagascar and South Island, New Zealand

25 Contrast and compare the climates of Northern China and China south of the Si Kiang, and compare each of the above with the climates of eastern North America in corresponding latitudes

26 Compare the seasonal pressure changes over the continents and oceans in the Northern and Southern Hemispheres Select about 30° N and 30° S as the latitudes for your comparison

27 What data are required before an isothermal map of a region can be drawn? In the case of the British Isles state what records are available

THE GEOGRAPHY OF PLANTS AND ANIMALS

28 Describe the distribution of coniferous forests in Europe and Asia, and say how far these forests are developed economically

29 Discuss the large-scale production of rice outside the monsoon lands of Asia

30 Write a brief description of the dairying industry of New Zealand and its place in the dairying industries of the world

31 What geographical factors have led to the immense wool production of the Southern Hemisphere?

[1] See *Introduction to World Geography*, p 284 A Wilmore G Bell & Sons

32 State the regions where the following are produced on the large scale in Africa, and discuss the factors which have led to that production—cocoa, coffee, cotton, palm-oil

33 Discuss and explain the following approximate statistics

A Acreage of arable land and in permanent grass for pasture in Scotland and Ireland

	Arable Land	*Permanent Grass*
Scotland	3 11 million acres	9 12 million acres
Ireland	4 67 „ „	1 55 „ „

B Numbers of sheep and cattle in Scotland and Ireland

	Sheep	*Cattle*
Scotland	7 56 million	1 23 million
Ireland	3 88 „	4 86 „

HUMAN GEOGRAPHY

34 Give some account of the peoples who inhabit Finland, Hungary, and Bohemia, including what you know of their race, language, and religion Describe the geographical environment briefly and show how it has influenced their industries and mode of life

35 South America as a whole is a sparsely peopled continent Select three different types of regions in that continent which are very sparsely peopled, and explain why

36 Discuss the distribution of population in Australia

37 What parts of Africa and South America seem to you to be suitable as possible fields for settlement by British emigrants ?

38 Show how the distribution of population in India is related to the geographical environment

39 Analyse the distribution of population in England north of the Trent

40 What is meant by the saying that the U S A. is the most important neighbour of the British Empire ?

THE APPENDIX MATHEMATICAL GEOGRAPHY

41 Describe the mode of construction of any map net which shows relative areas correctly, and point out its deficiencies Similarly describe one which shows directions correctly

42 State the chief properties of the following map nets, and say for what purpose each is best adapted Mercator's, Bonne's, Mollweide's

GLOSSARY

Ambas.—Blocks of rocks left by dissection of rivers in Abyssinia; cf. mesas of Dakota, Colorado, etc. Word of Abyssinian origin.

Andesite.—Lava of intermediate composition, *i.e.* containing about 55–60 per cent. silica; from the Andes, where these rocks are common.

Anemometer.—An instrument for measuring the force or the velocity of the wind. Greek, *anemos*, wind.

Anthropoid.—Man-like, applied to apes. Greek, *anthropos*, man.

Anticline.—Applied to stratified rocks; strata curved over in an archlike form. Greek, *anti*, against; *klinō*, slope.

Archæan.—Very old (applied to rocks); the oldest rock-system known. Greek, *archaios*, very old.

Arenaceous.—Sandy; applied to sedimentary and aqueous rocks.

Argillaceous.—Clayey; applied to sedimentary and aqueous rocks.

Armorican.—A system of earth-folds and fragments of old mountains in Western Europe. From Armorica, the Roman name for Brittany.

Artesian.—Wells or bore-holes which derive water from a deep syncline; from Artois, in France, where such wells or bore holes were first sunk.

Aryan.—A name used to designate a group of Eurasian peoples and the languages spoken by most of them. From the Sanskrit *arya*, noble, or of good family.

Asphalte.—Natural pitch found in Switzerland, Trinidad, etc. Greek and Latin, *asphaltos* and *asphaltum*.

Azimuth.—An arc of the horizon between the south point and the vertical circle through the centre of an object. From the Arabic.

Ballons sondes.—Free, unmanned balloons which carry self-recording instruments.

Bar.—An atmospheric pressure of 1,000,000 dynes per square centimetre. Greek, *baros*, heavy.

Basalt.—Lava of basic composition, *i.e.* containing less than 55 per cent. silica. The word is one of the oldest in Science, used by Pliny and Agricola; from Latin, *basaltes*.

Billabongs.—Cut-off lakes, found in the alluvial plains near the Australian rivers, cf the ox bow lakes of the Lower Mississippi Name of Australian origin

Breccia.—A rock formed of angular fragments cemented together Of Italian origin, cf French, *brèche*, a breach, something broken

Caatinga—Tropical thornwood region where the dry season lasts from six to eight months Thorny bushes and acacias form an important part of the vegetation Name of South American origin

Cainozoic—A group of rock systems, a geological era Greek, *kainos*, recent, new, *zoē*, life Hence, the era of newer or recent life, considered geologically

Calcareous—Limey, applied to sedimentary and aqueous rocks Latin, *calx*, lime

Caliche—A deposit of impure sodium nitrate, $NaNO_3$ found in the dry regions of Chile and Peru

Cambrian—A system of rocks Cambria, the Roman name for Wales The rocks are well developed in Wales where they were first thoroughly studied

Cañons.—Deep narrow, steep-sided valleys, cut by rivers in approximately horizontal strata Name of Spanish origin, from *caña*, a tube

Carboniferous—A system of rocks in Britain and many other regions, containing abundant coal-seams Latin *carbo*, coal and *fero*, I bear

Caribou—An American variety of reindeer Word probably of Indian origin

Cassava—A starchy food-stuff obtained from the manioc or tapioca plant French, *cassave*, Spanish, *cassabe*

Chinook—A warm, dry wind frequently experienced on the eastern side of the Rocky Mountains, cf *föhn*, wind of the Alps Name from Chinook Indians who lived in the Columbia River regions

Cluses—Transverse river-gaps cut through the longitudinal folds of the Jura Mountains Latin, *clūsa*, *clausa*, a shut-up place

Coir.—The husk or outside covering of the coco-nut, used in making ropes, sailcloth matting, etc Word of Malay origin, Malay *kayar*

Colza—A variety of cabbage, the seeds of which, when pressed, yield an oil used for burning French, *colzat*, probably from Dutch, *kool*, cabbage, *zaad*, seed

Copra—The dried kernel of the coco nut Word of Hindustani origin

Co-tidal lines—Lines drawn through places which have high tide at the same time

Cretaceous—A system of rocks Latin, *creta*, chalk.

Czechs.—A Slavonic people inhabiting Bohemia

Deciduous—Applied to trees leaves fall in the autumn Latin, *de* down *cado*, fall

Devonian—A system of rocks Name from Devonshire where the rocks are well developed

Dolines, dolinas—Natural funnel-shaped water-sinks found in the limestone of Dalmatia, etc Word of Russian origin

Dolomite—A mineral or rock-constituent composed of calcium and magnesium carbonates Named after Dolomieu the French geologist

Durra—A species of grain cultivated in India Arabia and the Mediterranean lands, known also as Indian millet and as Guinea corn Word of Arabian origin

Dynamic—Applied here to pressure as the result of motion pertaining to motion Greek, *dynamikos* powerful

Ecliptic—A great circle on the globe making an angle of nearly $23\frac{1}{2}°$ ($23° 27'$) with the equator, the plane of the earth's orbit extended to meet the celestial sphere Greek *ecleipo*, *eclipticus* pertaining to an eclipse

Ecology—The study of plant life and plant associations as determined by their environment Greek, *oikos*, home *logos*, speech, discourse

Eocene—A system of rocks Greek, *eōs* dawn *kainos* recent

Equinox—The time at which the sun crosses the equator (about 21st March and 22nd–23rd September) Latin, *æquinoctium*, *æquus* equal *nox* *noctis*, night

Erosion—Applied to rocks "eating," or wearing away by frost rain, rivers the sea, glaciers, winds, etc French, *éroder* from Latin, *e*, out of *rodere*, to gnaw

Escarpment—A steep cliff, usually applied to an inland cliff There is usually a steep face or cliff and the rocks lie horizontally or with a gentle dip away from it French, *escarper*, cut steeply

Estuary—An opening of the sea where the tide meets a river current Latin, *æstus*, the tide

Etangs—Lagoon like lakes cut off by sand dunes near a coast especially on coast of France Word probably of French origin

Etesian—Greek, *etesios*, yearly

Fiards—Openings compared with fiords, not so deep

Fiords—Long, narrow, deep openings usually with steep, rocky banks Type found in west of Norway Norwegian, *fjord*

Fohn—A warm, dry wind frequently experienced on the northern slopes of the Alpine ranges of Europe Local name used in the Swiss Alps possibly from Latin, *flavonius* Cf Chinook wind of Rocky Mountains

Fohrden—Branching shallow openings in the east of Denmark Name of local origin

Gabbro.—A basic, plutonic rock, allied in chemical composition to basalt Name of Italian origin

Gambier.—A tanning material obtained from the Malay States Name from Malay, *gambir*

Gault —A clay formation found in the Cretaceous system of Britain Name of English origin

Geest.—Sandy, dry, and somewhat barren land in the Netherlands Name of Frisian origin

Gneiss —A metamorphic, crystalline rock having its component minerals arranged in irregular folia German *gneiss*, probably an old miner's term

Gnomonic —Having some similarity to the reading of a dial Greek, *gnomon*, the index of a sun-dial

Graticule —Literally a little grate Applied in geography to the network or cross-lines of latitude and longitude on a map

Haff —A shallow lagoon or bay inside a long spit of sand on the Prussian Baltic coast German, *haff*

Homolographic —Drawn so as to have equivalent areas Greek, *homolos*, agreeing

Horst —A portion of the earth's crust standing above neighbouring portions which have been depressed by faulting German, *horst*

Hygrometer —An instrument for measuring the degree of moisture of the atmosphere Greek, *hygros*, wet, moist

Insolation —Exposure to the sun's rays, in modified usage it means effective solar radiation on a part of the earth's surface Latin, insolation from verb *insolo*, *in*, in, and *sol*, the sun

Ions —The substances which appear at the respective poles in electrolysis, the electrically charged atoms into which a salt is supposed to be more or less decomposed in solution Greek, *ion*, from the verb to go

Isallobars —Lines drawn through places where the amount of change of pressure is the same since the preceding observation, hence lines of equal change of pressure Greek, *isos*, equal, *allos*, other, *baros*, weight

Isobar —A line passing through places which have the same atmospheric pressure Greek, *isos*, equal, *baros*, weight

Isotherm —A line passing through places which have the same temperature Greek, *isos*, equal, *thermos*, hot

Jurassic —A system of rocks The name comes from the Jura Mountains, where rocks of this age are well developed

Lianas —Twining tropical plants which climb up the stems and branches of trees in tropical countries French, *lier*, to bind

Limans.—Lagoons on the shore of the Black Sea. Name of Russian origin, probably from Greek *limen*, harbour.

Lithosphere.—The solid part of the earth as distinguished from the atmosphere and the hydrosphere. Greek, *lithos*, a stone; *sphaira*, sphere.

Loess.—A pale yellow homogeneous calcareous loam or clay or very fine sand. Name of German origin.

Mamelon.—A rounded volcanic hill. French *mamelon*, nipple.

Meridian.—A great circle on the globe passing through the poles and any given place. A great circle of the celestial sphere passing through its poles and the zenith of any given place. Latin *meridies*, midday.

Mesas.—Table-lands dissected by rivers in Dakota, that is, the region is cut up into separate "tables." Spanish *mesa*, table.

Mesozoic.—An era of geological time, and a group of rock systems. Greek *mesos*, middle; *zoē*, life. Cf. Cainozoic.

Millibar.—One-thousandth of a bar (*q.v.*), the unit of atmospheric pressure.

Miocene.—A system of rocks. Greek *meion*, less; *kainos*, recent.

Nehrung.—A narrow tongue or spit of land, a long sandbank on the Baltic coast of Prussia. German *nehrung*.

Neolithic.—The later or newer Stone Age. Greek *neos*, new; *lithos*, stone. Applied to the history of early man as revealed by his weapons and tools.

Oblate.—Flattened or depressed at or round the poles. Greek, *oblatus*, facing.

Oligocene.—A system of rocks. Greek *oligos*, few; *kainos*, recent.

Ordovician.—A system of rocks. Named from the Ordovices, a tribe of ancient Britons who inhabited the region in Wales where these rocks were studied by Lapworth.

Orographic.—Representing the mountains, valleys, plains, etc., of a region. Greek, *oros*, a mountain.

Orthographic.—Pertaining to right lines or right angles; used in that sense in projection. Greek *orthos*, right.

Orthomorphic.—Right in shape or direction; used in that sense in map projections.

Palæolithic.—The earlier or older Stone Age. Greek, *palaios*, ancient; *lithos*, stone. Cf. Neolithic.

Palæozoic.—An era of geological time and a group of rock systems. Greek, *palaios*, ancient; *zoē*, life. Cf. Cainozoic and Mesozoic.

Pampas.—Treeless grassy plains in the temperate regions of South America. Spanish, *pampa*, a plain.

Permian —A system of rocks From Perm, in Russia, where rocks of this age are well developed, and where they were studied by Murchison

Pleistocene —A system of rocks Greek, *pleistos*, most, *kainos*, recent.

Pliocene —A system of rocks Greek, *pleion*, more, *kainos*, recent

Plutonic —Igneous rocks which have solidified at some depth, and under great pressure Greek, *Pluto*, the god of the underworld

Polyen —Enclosed valleys in the limestone region of Illyria and Dalmatia They are usually drained by " water-sinks " in the limestone Name of local origin

Pusstas —Steppe-like plains in Lower Hungary Name of Hungarian origin

Puys —Conical, volcanic hills in the Auvergne, France French, *appui*

Quader-sandstein—*Quader* = square, cubical, *sandstein*, German for sandstone A sandstone in the N E of Bohemia which weathers into great cubical blocks

Rhyolite —An acid volcanic rock, a lava with a chemical composition similar to granite Greek, *rhyax*, stream, *lithos*, stone

Ria —A river-mouth, used by Richtofen for a special type of opening Spanish, *ria*

Rift-valley —A valley let down between two somewhat parallel faults

Savana or Savanna —A grassy plain in tropical America, now used for tropical grassy plains with scattered timber Spanish, *savana*, *sabana*

Schist —A metamorphic rock that splits into thin irregular laminæ or folia French, *schiste*, Latin, *schistos*, Greek, *schistos*, cleavage or splitting

Scoria —Cellular, cindery lava, fragments of lava Italian, from Latin and Greek, *skōria*, dung refuse

Selvas —The dense woodlands of the Amazon basin, used for similar equatorial forest plains elsewhere Latin, *silva* forest

Serpentine —A mineral or rock consisting chiefly of hydrated magnesium silicate, a much-altered ultra-basic rock, markings supposed to suggest those of a serpent

Shotts —Salt-lakes in the Atlas region of North Africa Name of Arabic origin Cf *shat*, an estuary, Arabic

Sierra —Applied to mountain-chains which have a saw-like profile Spanish from Latin *serra*, a saw

Sill (igneous) —Used for an intrusive sheet of igneous rock Remotely connected with Latin, *sella*, from *sedeo*, through French, *selle*

Silurian.—A system of rocks. Named from the Silures, a tribe of ancient Britons who inhabited the Welsh Borderland where Murchison studied the rocks.

Sinter.—Material deposited by springs, especially hot springs. German *sinder*. Cf. English "cinder."

Sinusoidal.—Pertaining to sines; containing sine curves.

Solstice.—The time of the year when the sun reaches its highest declination either north or south of the equator (21st June, 21st December). Latin *sol*, sun; *sto*, to stand.

Spheroid.—A figure having nearly the form of a sphere; a figure made by rotating an ellipse round one of its axes.

Static.—At rest; opposed to dynamic. Greek, *statikos*, bringing to rest.

Stereographic.—Pertaining to the art of depicting a solid body on a plane surface. Greek *stereos*, solid.

Stratosphere.—The layer of the atmosphere in which there is practically no fall of temperature with increasing height. Latin *stratum*, a layer; and sphere as before.

Sudd.—A floating mass of vegetation which obstructs the flow of the White Nile. Name of Arabic origin.

Syncline.—Strata dipping towards an axis in trough-like form. Greek, *syn*, together; *klino*, I bend.

Taiga.—The coniferous forest of Russia and Siberia. Name of Russian origin; now used for such forests elsewhere.

Tchernozoum.—Fertile black soil in S.W. Russia. Name of Russian origin.

Tectonic.—Connected with the building of the earth's crust. Latin *tectonicus*; Greek *tektonikos*. Greek *tekton*, a maker or builder or carpenter.

Terai.—A swampy belt in Northern India at the foot of the Himalaya. Name of Hindustani origin.

Theodolite.—An instrument for measuring horizontal and usually vertical angles.

Topographic.—(In maps) representing the features of a region, its relief, its rivers, lakes, cities, etc. Greek *topos*, a place.

Trachyte.—A lava or volcanic rock of intermediate composition; contains about 60–65 per cent silica; chemical composition similar to syenite. Greek *trachys*, rough.

Triassic.—A system of rocks. Greek *trias*, from *treis*, three. There are three distinct divisions in Central Europe.

Tropopause.—The boundary between the troposphere (*q.v.*) and the stratosphere (*q.v.*); the place where the vertical temperature gradient ceases. Greek *tropos*, a change or turning.

Troposphere.—The layer of the atmosphere in which there is a fall of temperature with increasing height.

Tuff.—Fragmental volcanic matter ejected in explosive outbursts. French *tuf*, from Italian *tufa*.

Tundra.—The frozen desert plains of Russia, Siberia, and North America. Name of Russian origin.

Variscan.—Applied to the old, broken and dissected mountains of Central Europe. Variscia, ancient Germany.

Veld (veldt).—The open, pasturage country in South Africa. Dutch, *veldt*, dry country.

Wadden (watten).—The lagoons behind the sand dunes of the Netherlands. Word of Dutch origin. Cf. old English "wade" and "watter."

Zenith.—The point of the heavens vertically above the observer. From the Arabic.

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